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RCRA PERMIT MODIFICATIONS AND THE FUNCTIONAL EQUIVALENCY DEMONSTRATION: A CASE STUDY

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RCRA PERMIT MODIFICATIONS AND THE FUNCTIONAL EQUIVALENCY DEMONSTRATION: A CASE STUDY

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Absract

Hazardous waste operating permits issued under the Resource Conservation and Recovery Act (RCRA) often impose requirements, typically by reference to the original permit application, that specific components and equipment be used. Consequently, changing these items, even for the purpose of routine maintenance, may first require that the owner/operator request a potentially time-consuming and costly permit modification. However, the owner/operator may demonstrate that a modification is not required because the planned changes are "functionally equivalent," as defined by RCRA, to the original specifications embodied by the permit.

The Controlled-Air Incinerator at Los Alamos National Laboratory is scheduled for maintenance and improvements that involve replacement of components. The incinerator's carbon adsorption unit/high efficiency particulate air filtration system, in particular, was redesigned to improve reliability and minimize maintenance. A study was performed to determine whether the redesigned unit would qualify as functionally equivalent to the original component. In performing this study, the following steps were taken: (a) the key performance factors were identified; (b) performance data describing the existing unit were obtained; (c) performance of both the existing and redesigned units was simulated; and (d) the performance data were compared to ascertain whether the components could qualify as functionally equivalent.

In this case, the key performance data included gas residence time and distribution of flow over the activated carbon. Because both units were custom designed and fabricated, a simple comparison of manufacturers' specifications was impossible. Therefore, numerical simulation of each unit design was performed using the TEMPEST thermal-hydraulic computer code to model isothermal hydrodynamic performance under steady-state conditions. The results of residence time calculations from the model were coupled with flow proportion and sampled using a Monte Carlo-style simulation to derive distributions that describe the predicted residence times. The results showed that the redesigned unit, although physically different in many aspects, is equivalent in performance to the existing unit, thereby obviating the need to seek a permit modification. By using this approach to demonstrate the functional equivalency of the redesigned unit, it is estimated that $1 million allocated to perform a trial burn was saved.

Introduction

The Los Alamos National Laboratory's (LANL's) Controlled-Air Incinerator (CAI) has recently undergone maintenance and improvements that involved replacement of components. The CAI carbon adsorption unit, in particular, was redesigned to improve reliability and minimize maintenance requirements. This study compared the hydrodynamic performance of the existing activated carbon adsorption unit/high efficiency particulate air (HEPA) filtration system and the proposed upgrade of the system. The purpose was to determine whether the changes can be considered "functionally equivalent" pursuant to regulations promulgated under the Resource Conservation and Recovery Act (RCRA) at 40 CFR §270.2 (1).

The CAI was originally intended to process small amounts of waste for research purposes only, so the specifications for the materials of construction did not consider the rigors and stresses of continuous operation, particularly those relating to corrosion. The existing carbon adsorption unit is constructed of low-carbon steel, a corrosion-prone material. Also, the angle of the carbon bed is thought to inhibit efficient filling of the bed with carbon and allows carbon particles to escape through the screen, which may encourage bridging of the media.

In order to maintain the current operational parameters and minimize the potential for a major RCRA permit modification, as discussed below, the proposed unit design is based on the same primary design criterion as the existing unit, namely, a gas-carbon contact time of 0.5 second. This criterion is based on *Nuclear Power Plant Air Cleaning Units/Components*, Section 5.2.2, "Adsorber Design," which requires that for the removal of gaseous iodine the minimum residence time of a gas stream in an adsorbent be 0.25 second (2). The current unit is designed to a minimum residence time of 0.5 second because a safety factor of 2.0 was used in the original design.

Regulatory Considerations

To burn hazardous and mixed radioactive waste, the CAI must operate under the provisions of LANL's Hazardous Waste Facility Permit issued by the New Mexico Environment Department (NMED) (3). Under RCRA, any proposed changes to a permitted facility must be evaluated to determine whether the changes require a modification to the permit. The requirement for a permit modification and its magnitude, or "Class," are determined using specific criteria. The general criteria that define the modification class are specified in 40 CFR §270.42(d)(2) as follows:

(i) *Class 1 modifications* apply to minor changes that keep the permit current with routine changes to the facility or its operation. These changes do not substantially alter the permit conditions or reduce the capacity of the facility to protect human health and the environment. In the case of Class 1 modifications, the Director may require prior approval.

(ii) *Class 2 modifications* apply to changes that are necessary to enable a permittee to respond, in a timely manner, to,
  (A) Common variations in the types and quantities of the wastes managed under the facility permit,
  (B) Technological advancements, and
  (C) Changes necessary to comply with new regulations, where these changes can be implemented without substantially changing the design specifications or management practices in the permit.

(iii) *Class 3 modifications* substantially alter the facility or its operation (1).

Each class requires a different level of response from the permittee and different levels of public involvement, Class 3 modifications being the most rigorous.

The carbon adsorption unit is not specifically described in LANL's permit as it is currently written (3). Therefore, a physical change to this particular apparatus does not automatically require a modification to the permit unless the NMED determines that it causes or justifies a change to the permit conditions (40 CFR §270.41(a)(1)) (1). The only permit condition that applies to the carbon adsorption unit is a requirement to replace the spent carbon; this requirement will still be met after the proposed unit is installed.

The primary concern of CAI staff was the potential for the upgrade to require a Class 3 permit modification, as specified in Appendix I to §270.42, item L(3).

> Modification of an incinerator, boiler, or industrial furnace unit by changing the internal size or geometry of the primary or secondary combustion units, by adding a primary or secondary combustion unit, *by substantially changing the design of any component used to remove HCl/Cl_2, metals, or particulate from the combustion gases, or by changing other features* of the incinerator, boiler, or industrial furnace *that could affect its capability to meet the regulatory performance standards....* [This is a Class 3 modification]. (1)
> (emphasis added)

The carbon adsorption unit is designed to remove radioactive isotopes of iodine, which is neither a particulate nor a metal. Hydrogen chloride (HCl) and chlorine (Cl_2) are removed in the venturi scrubber and the absorber column, respectively. The unit may contribute to the removal of organic compounds, but its capacity in this regard has never been assessed, except through the overall destruction and removal efficiency (DRE) established for the entire CAI during the trial burn. That is the root of the problem for the CAI, because the last part of the citation above describes any change that *could* affect the ability to meet performance standards.

However, if the facility can demonstrate that the upgraded equipment is functionally equivalent to the equipment that it replaces, there is no longer a basis for assuming that the change would affect performance. Functionally equivalent components are defined in the regulations as follows:

> *Functionally equivalent component* means a component that performs the same function or measure and which meets or exceeds the performance specification of another component (40 CFR §270.2).

In fact, upgrading with functionally equivalent components is a specific type of Class 1 modification listed in Appendix I of Part 270:

> Equipment replacement or upgrading with functionally equivalent components [is a Class 1 modification] (1).

To better define the circumstances that constitute this type of modification, the EPA stated in the preamble to the revised 40 CFR Part 270 that:

> Under Item A(3), permittees are able to make routine equipment replacements that are necessary for the continued operation of the facility ... (however) some permit conditions may inadvertently create restrictions by incorporating portions of the Part B permit application by reference. For example, if a permit incorporates a design drawing by reference which specifies a particular piece of equipment ... then to replace the item with anything other than the original model might require a permit modification. Such an item may not be available ... *or the permittee may prefer to replace it with an improved version* ... Therefore, if it is necessary to include design drawings in permits, the permit condition should also allow minor deviations from the design without a permit modification (although the Director may want to have the permittee send the revised design to the Agency to maintain a current file on the facility) (53 FR 37924-37925, September 28, 1988) (4).
>
> Therefore, Item A(3) in the Appendix provides that equipment replacement or upgrading with functionally equivalent components is a Class 1 change (53 FR 37924, September 28, 1988) (4).
> (emphasis added)

It is clear, then, that if the proposed change to the design of the carbon adsorption unit could be demonstrated to be a replacement with a functionally equivalent component, it would not require a modification to the existing permit and at worst would have to follow the procedures for completing a Class 1 modification.

For the CAI, the difficulty arises from the unique nature of each unit's design. Under normal circumstances, manufacturer's performance data or other specifications could be used to demonstrate functional equivalency. However, because each unit was custom designed for application in the CAI, this was not possible. Instead, the existing and proposed unit designs were modeled using numerical simulation to perform a relative comparison of performance. The following describes the competing unit designs in general and the method used to perform a relative comparison between them.

Numerical Simulation

The hydrodynamic behavior of the two unit designs was modeled using several numerical simulations developed with the "Transient Energy, Momentum, and Pressure Equations Solutions in Three dimensions", or TEMPEST computer code (5). TEMPEST is a general purpose, three-dimensional, finite difference, hydrothermal analysis code with fully coupled heat transfer and fluid mechanics. The models simulated the physical configuration and operation of the two designs under actual operating conditions. Physical configuration data were taken from drawings of the two designs (6,7,8,9). Typical operating conditions and additional information on the operation of the CAI were taken from a report produced by T.K. Thompson, Inc. (10) and additional data provided by LANL. Operational data were also available from the CAI RCRA trial burn, conducted in 1989, which described operating conditions in the existing unit (10,11).

The primary design parameter for a carbon adsorption unit is the gas residence time. Treatment of the offgas occurs when it is in contact with the adsorption medium, which is granular activated carbon. The original unit was designed to the ANSI/ASME N509 standard which requires a minimum of 0.25 second bed contact time; this was increased to 0.50 second using a design safety factor of 2.0. Also of importance to adsorber design is the relative distribution of gas flow over and across the carbon bed. If the flow of gas is non-uniform across the bed, the flux of contaminants is also non-uniform. Traditional design assumes average flow and residence time in the bed based on bed cross-sectional area, length, and the volumetric flow rate of the offgas stream. However, the proposed unit design is complex, with a dual-pass configuration and cylindrical symmetry.

It was important to consider this because of a concern that both unit designs exhibited short-circuiting and preferential flow patterns. Preferential flow would in turn cause the actual residence times to be less than 0.50 second and use only a fraction of the available adsorption media. Therefore, it was determined that the distribution of gas flow through the carbon bed should be coupled with the gas residence times calculated from the TEMPEST simulations to produce a probability density function (PDF) for gas residence time. For the purposes of this analysis, the authors defined flow proportion as the fraction of the total gas flow moving through a discrete segment of the bed at any given time. Flow proportion was used as the measure of probability that the gas would achieve a particular residence time. The residence time PDF can then be used to statistically describe the uniformity of flow in each unit.

TEMPEST output provided gas velocities and pressure drops throughout the discretized internal volumes of both unit designs. The gas velocity distributions resulting from these simulations were then used to calculate gas residence time and flow proportion. Some of the necessary assumptions are listed below.

- Gas residence time is equivalent to treatment capacity.
- Gas residence time distributions correspond to the numerical simulation predictions of flow.
- The effects of non-uniform flow distribution are accounted for by using flow proportion as the measure of probability that the gas will achieve a particular residence time.
- Minimum residence time is equal to the minimum gas flow path length divided by the gas velocity component orthogonal to the carbon bed screen.
- Minimum gas flow path length is defined by the shortest path across the carbon bed (i.e., the carbon bed thickness).
- Carbon bed cells adjacent to the mid-axial barrier in the proposed cylindrical design can be ignored because of the lack of significant radial flow and the subsequent overestimation of gas residence time (residence times calculated by the simulations were truncated from the statistical analysis).

The cross-sections of the existing and proposed designs are shown in Figures 1 and 2, respectively. Nodalization into computational cells was carried into three-dimensions for both units. Flow and pressure distributions resulting from the numerical simulations of each unit design are shown in Figures 3 and 4. As can be seen from these diagrams, the flow in both units does not suggest that "average" flow conditions prevail in either unit. The existing unit simulations showed significant flow concentration in a small region near the top left-hand portion of the screen. The proposed unit simulations showed that flow was better distributed, with some concentration near the inlet and outlet ducts.

Functional Equivalency Determination

After the residence time PDFs had been generated, they were sampled using Monte Carlo-style simulations (i.e., random sampling of the distributions) to statistically describe them. This was necessary primarily due to the dual-pass design of the proposed unit. That is, it was assumed that flow path in the upper region was independent of flow in the lower region of the unit. Therefore, randomly sampling the residence time PDF for each region separately and summing the result would provide an accurate description of flow distribution and the distribution of residence times. The existing unit was a single pass design, but had to be analyzed similarly to maintain consistency.

Figures 7 and 8 show the resulting residence time distributions for the existing and proposed unit designs, respectively. Analysis of these distributions indicated that the proposed unit has a significantly greater proportion of flow that exceeds the 0.5 second requirement than the existing unit. The distributions also indicated that the volumetric flow of gas was better distributed in the proposed unit, thus offering potentially more efficient usage of carbon and a larger margin of safety for contaminant breakthrough. Based on the numerical simulations and subsequent analysis, the proposed design was determined to be functionally equivalent to the existing carbon adsorber unit in the CAI.

Conclusion

Because of the unique design and application of the carbon adsorber, manufacturer's performance data or other specifications could not be used to demonstrate functional equivalency. This necessitated a numerical simulation of the relative hydrodynamic performance of each design. The results of this simulation coupled with a statistical simulation technique provided the data necessary to determine that the proposed unit design was indeed functionally equivalent to the existing design. The approach used in this case successfully avoided the need for a potentially time-consuming and costly modification of the facility's hazardous waste operating permit. It is estimated that approximately $1 million was saved by avoiding a trial burn to evaluate the proposed unit's performance. This approach, in effect, sets a precedent for application at other permitted units to meet the compliance requirements of RCRA while minimizing costs and potential delays.

References

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2. ANSI/ASME N509, *Nuclear Power Plant Air Cleaning Units/Components*, American Society of Mechanical Engineers (1989).

3. *Hazardous Waste Facility Permit*, Permit No. NM 0890010515-1 issued to Los Alamos National Laboratory, New Mexico Environment Department (1989).

4. 53 FR 37915, "40 CFR Parts 124, 264, 265 and 270 Permit Modifications for Hazardous Waste Management Facilities; Final Rule," Federal Register 53: 37915-37942 (1988).

5. D.S. TRENT and E.E. EYLER, *TEMPEST: A Computer Program for Three-Dimensional Time-Dependent Hydrothermal Analysis, Volume 1: Users Manual*, Version N, Mod 33, Battelle Memorial Institute (1991).

6. LANL, *Carbon Bed Filter: Right Side Panel*, Drawing 103Y-223109, Sheet 4, Los Alamos National Laboratory (1986a).

7. LANL, *Carbon Bed Filter: Bottom Transition and Frame Assembly*, Drawing 103Y-223109, Sheet 7, Los Alamos National Laboratory (1986b).

8. LANL, *LANL CAI Carbon Bed: Shell Weldment Detail*, Drawing 103Y-2030, Sheet 3, Rev. 1, Los Alamos National Laboratory (1993a).

9. LANL, *LANL CAI Carbon Bed: Seal-Collar Weldment Detail*, Drawing 103Y-2030, Sheet 6, Rev. 1, Los Alamos National Laboratory (1993b).

10. J. FISHER, *CAI Carbon Adsorber Upgrade Design*, T.K. Thompson, Inc., Engineering Services (1993).

11. J.P. GARCIA, LANL, Letter Transmittal of Drawings and RCRA Trial Burn Data (CST-7D-94-001) to J. Kinker, Benchmark Environmental Corporation (January 4, 1994).

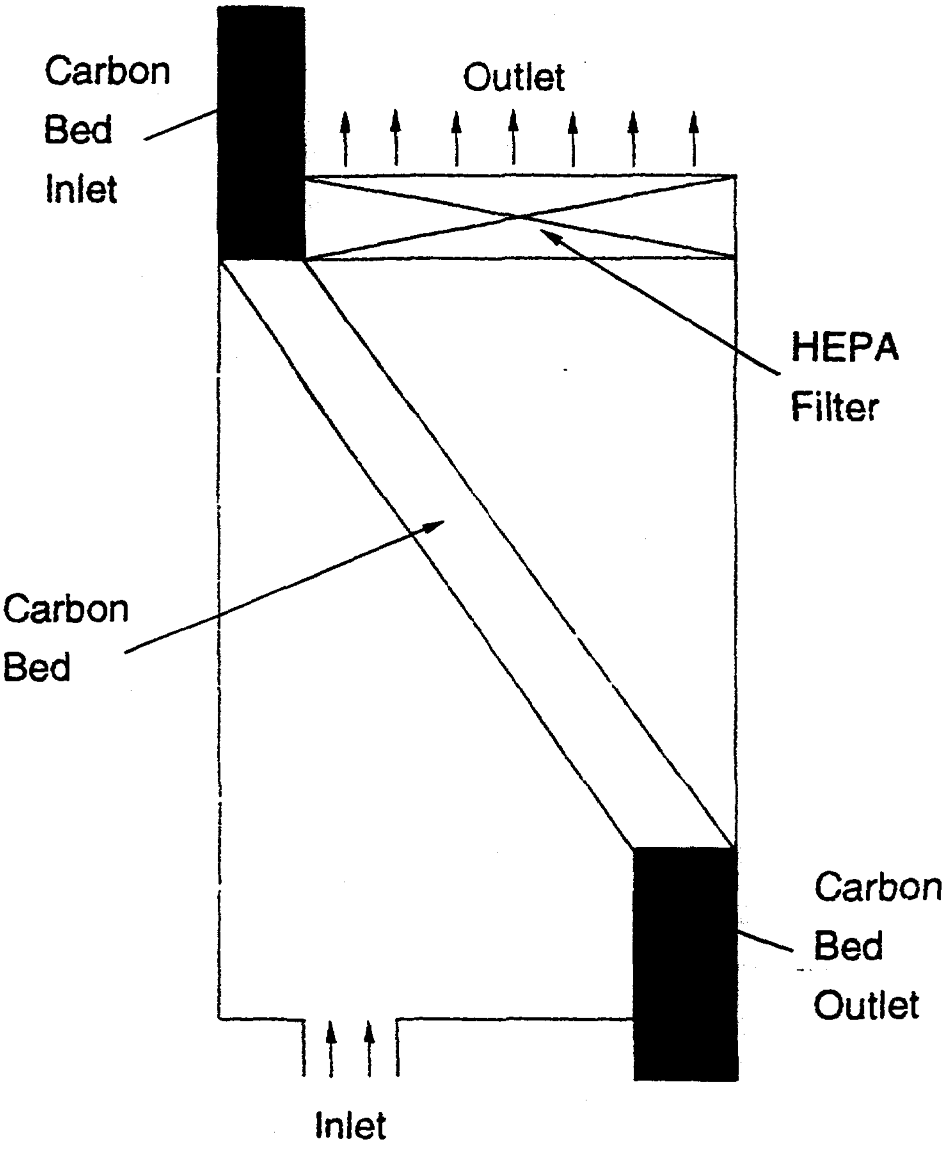

FIGURE #1

Diagram of Existing Unit Design

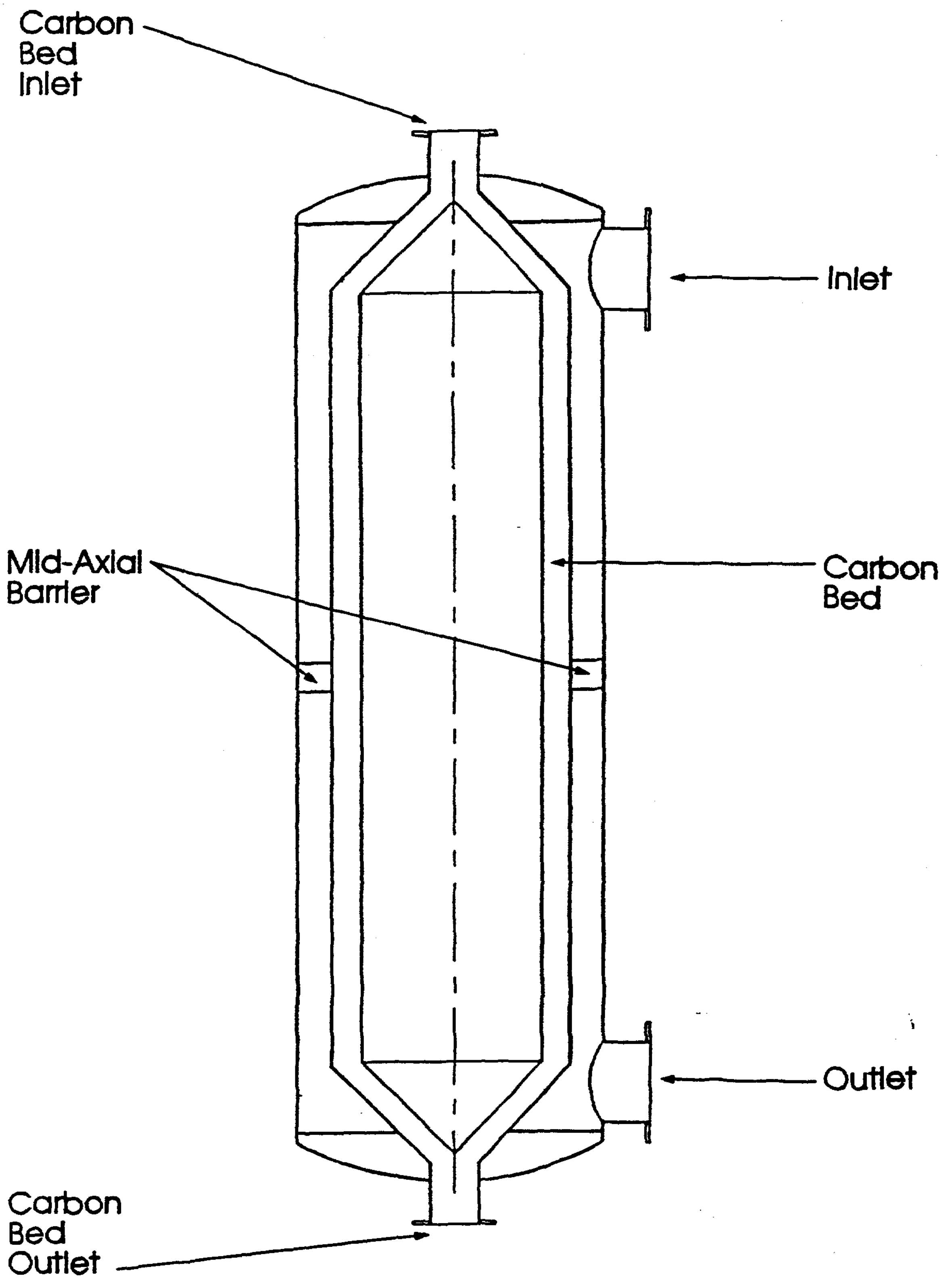

FIGURE [illegible]-2

Diagram of Proposed Unit Design

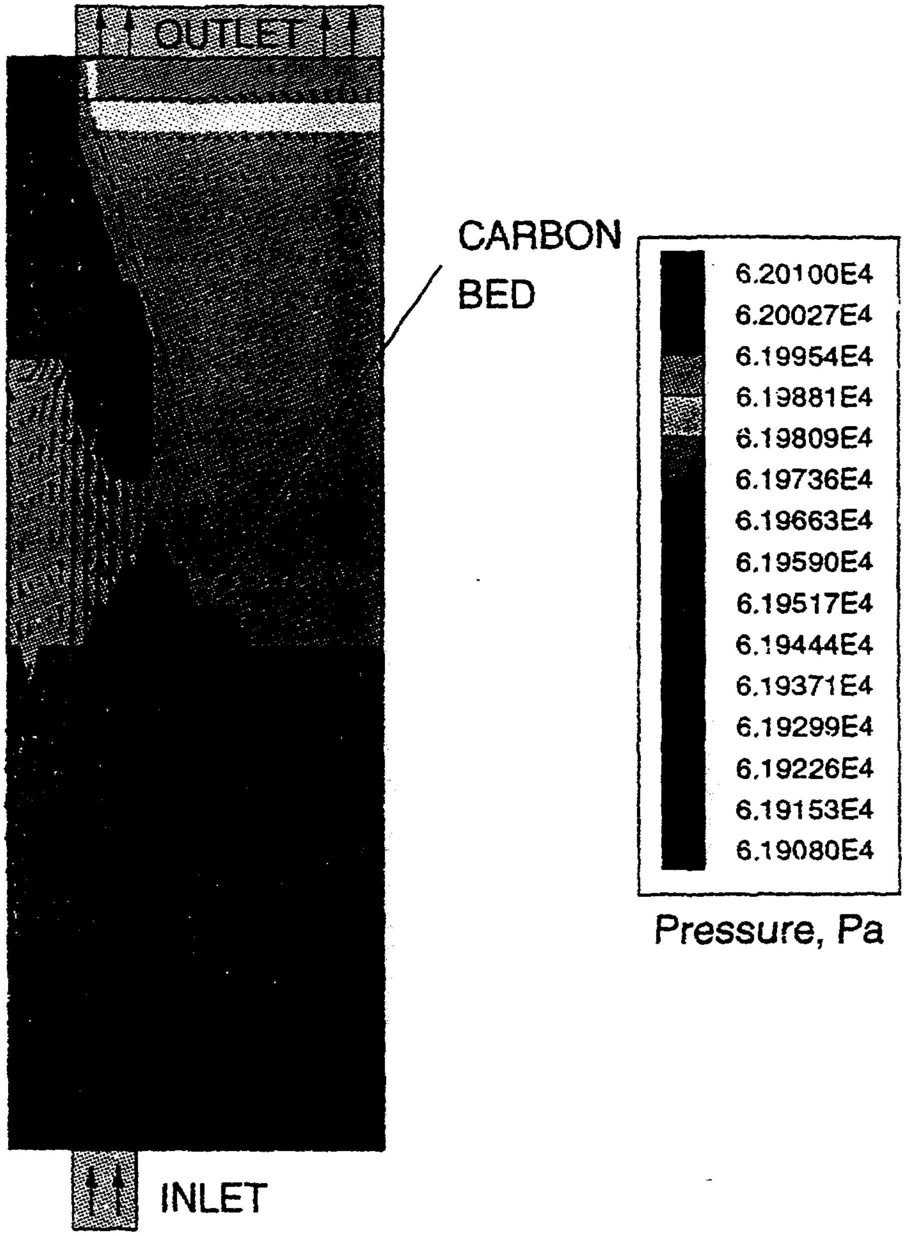

FIGURE 3[illegible]

Flow and Pressure Distribution for the Existing Unit

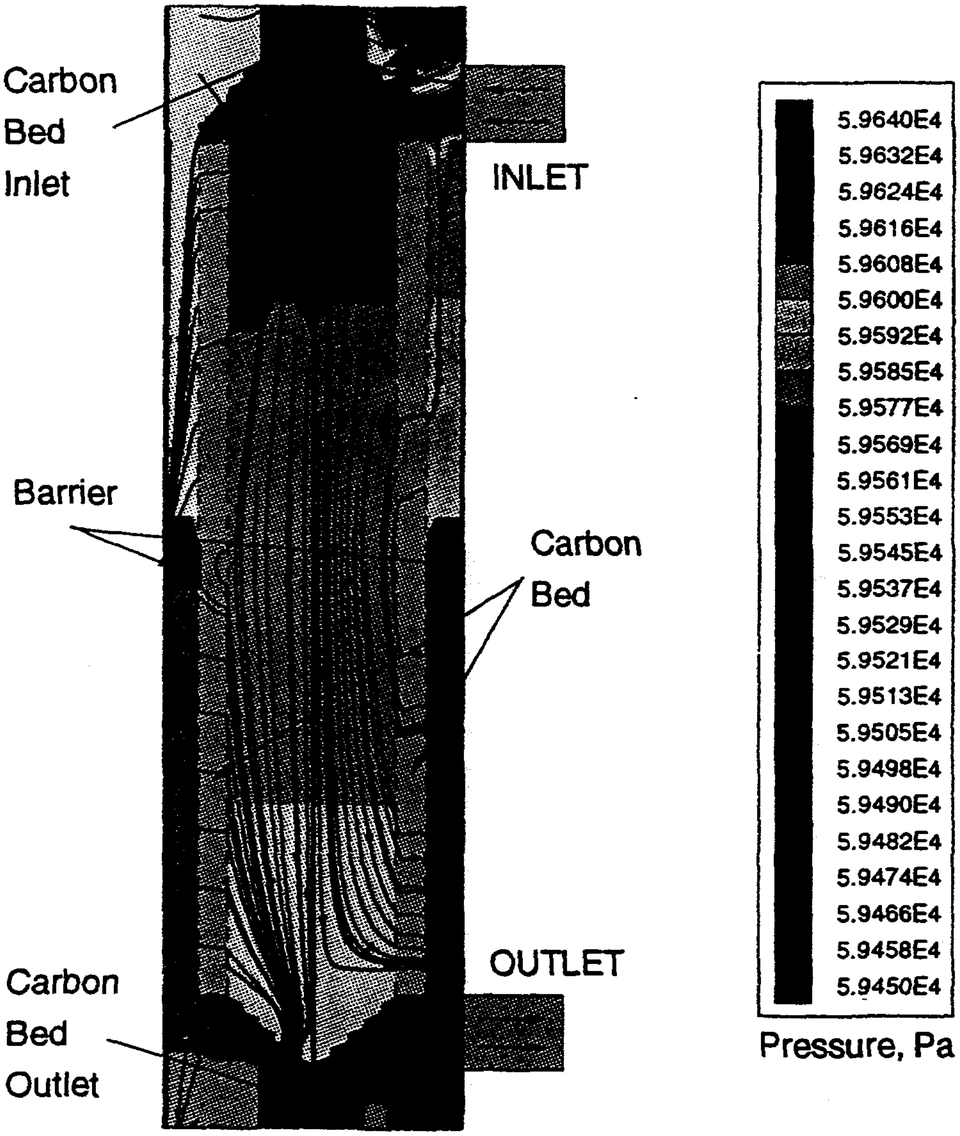

FIGURE 4

Flow and Pressure Distribution for the Proposed Unit

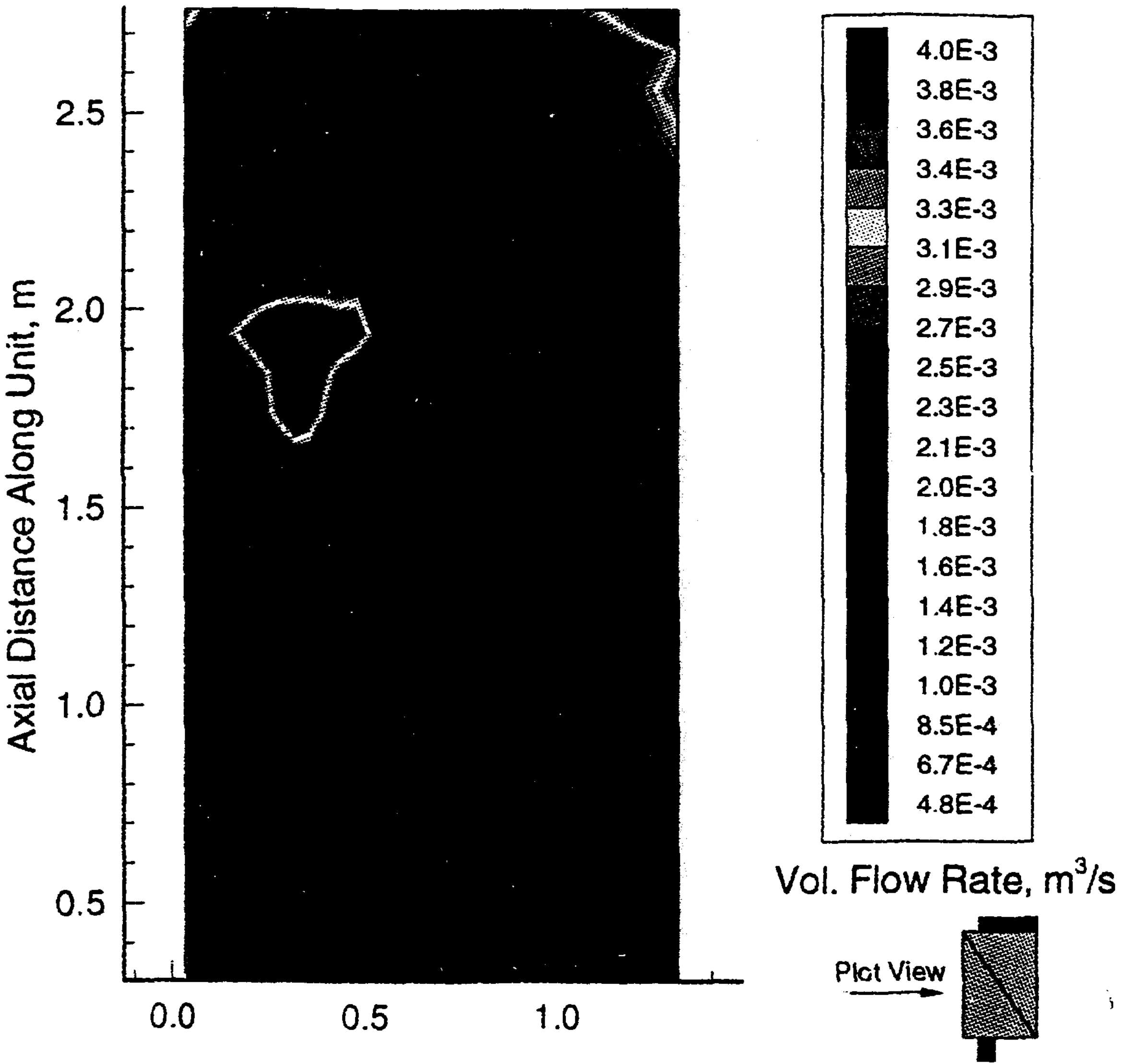

FIGURE ~~4a~~ 5

Distribution of Volumetric Flowrate Across Existing Unit Carbon Bed

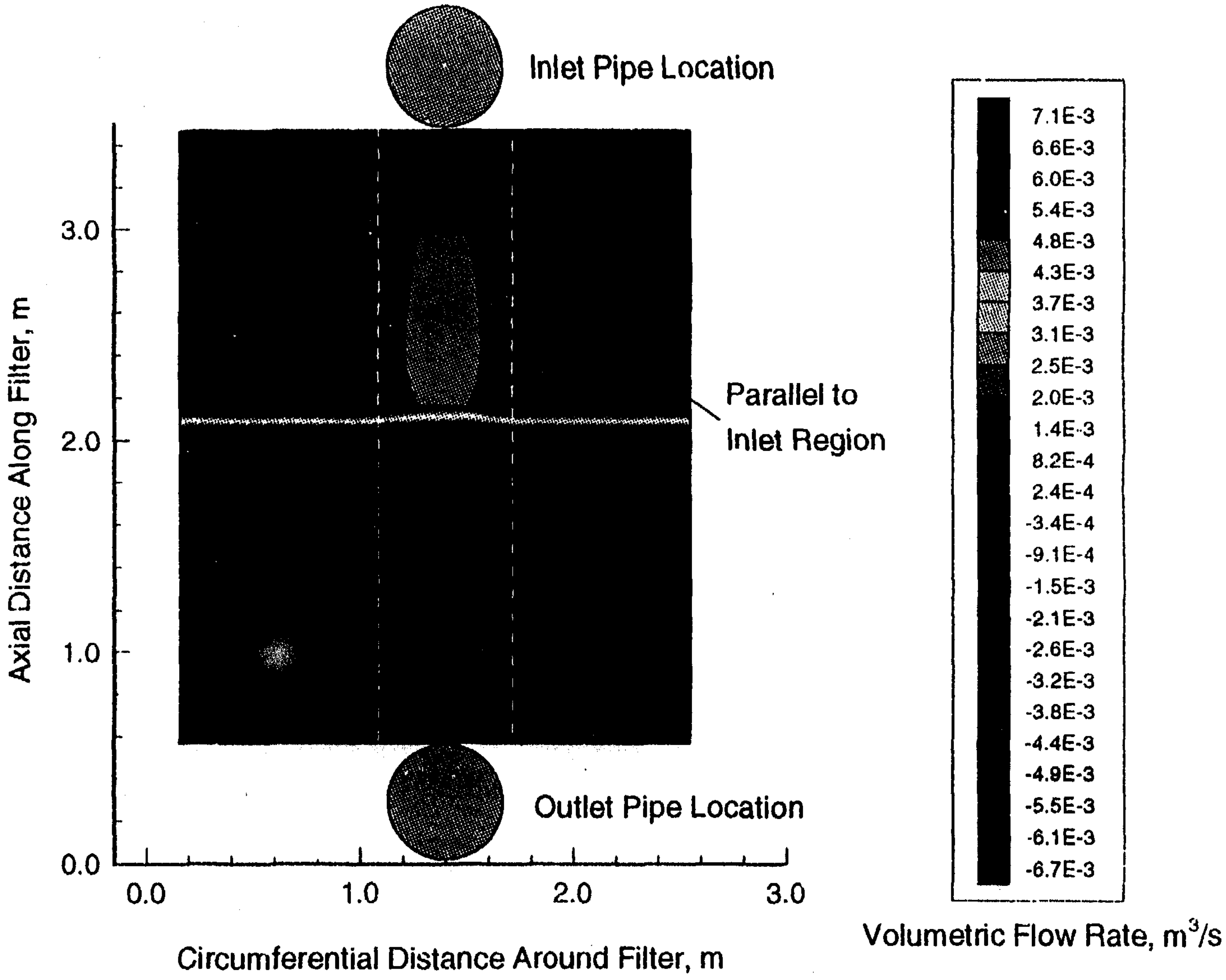

FIGURE 6

Distribution of Volumetric Flowrate across Proposed Unit Carbon Bed

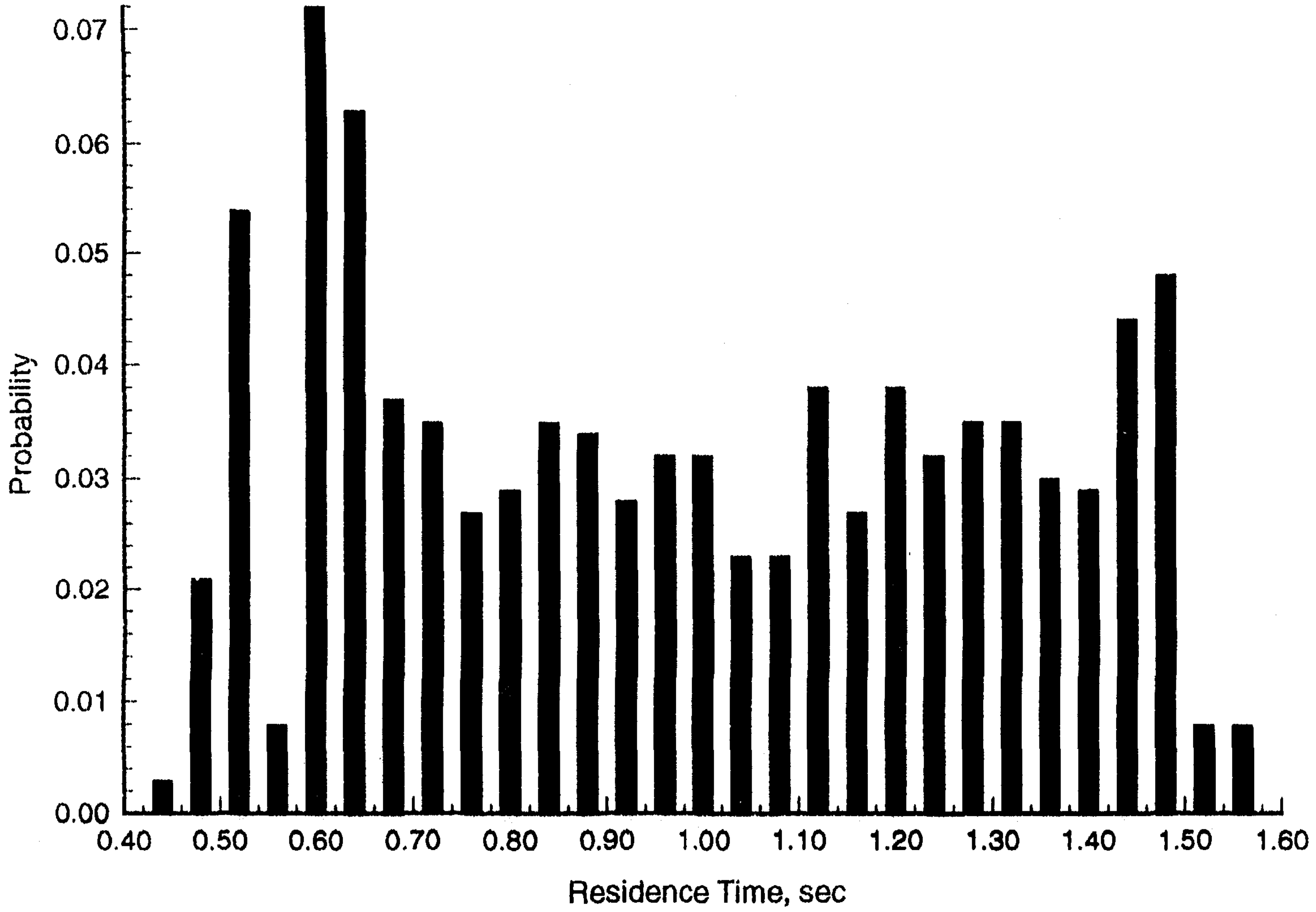

FIGURE 7

Histogram of Simulated Distribution of Residence Time for Proposed Unit

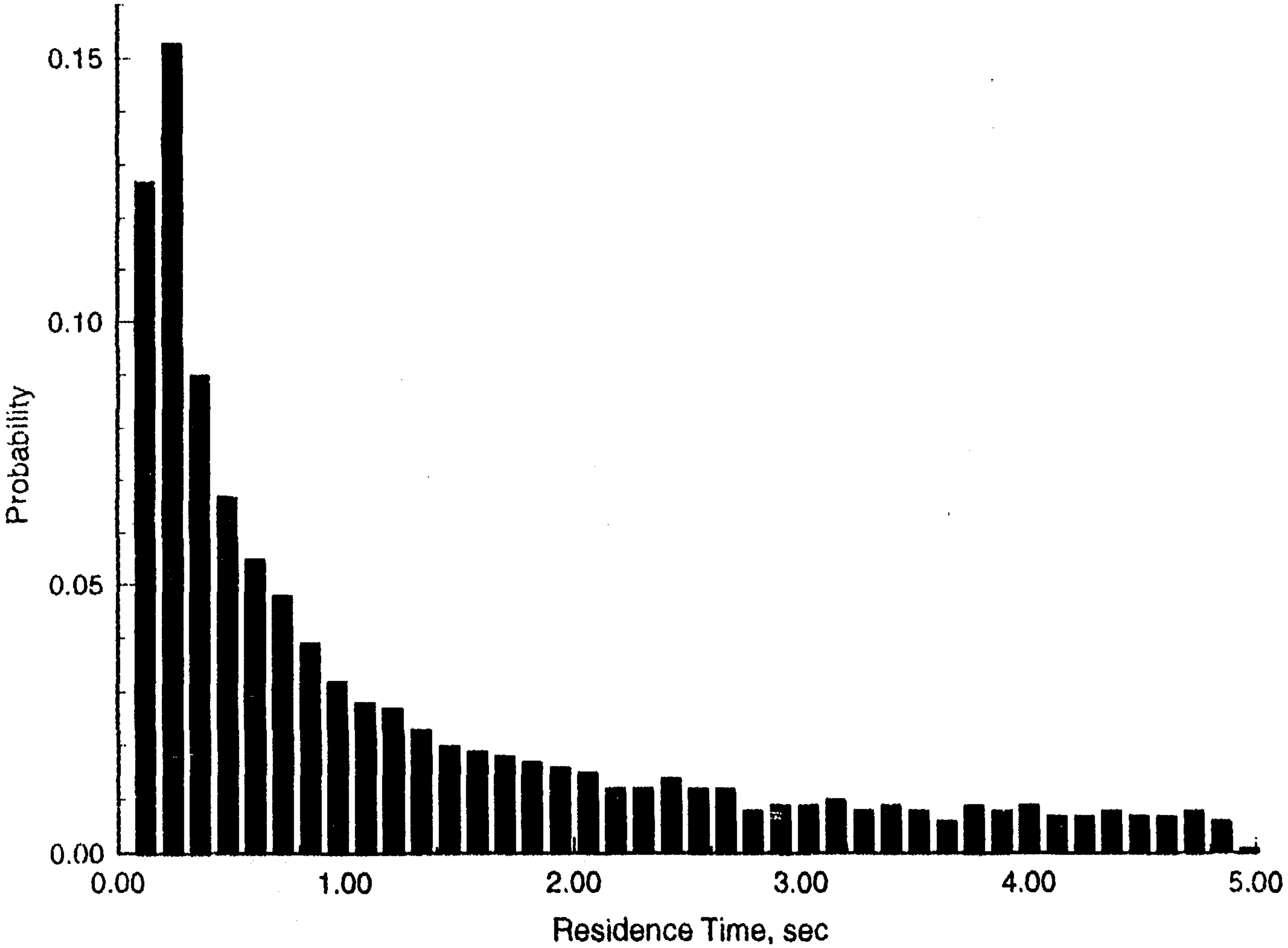

FIGURE [illegible]-6

Histogram of Simulated Distribution of Residence Time for Existing Unit