

AD NO. _____
TECOM PROJECT NO. 9-CO-160-000-374
REPORT NO. ATC-8115
AEC SFIM-AEC-ER-CR-98030

FINAL REPORT
OF THE
COALESCING TUBES TEST
FOR OIL/WATER SEPARATORS (OWSs)

PAUL C. KLARA, P.E.
CHEMISTRY TEAM
SOLDIER AND FOREIGN SYSTEMS

U.S. ARMY ABERDEEN TEST CENTER
ABERDEEN PROVING GROUND, MD 21005-5059

SEPTEMBER 1998

Period covered:
December 1997 to May 1998

Prepared for:
U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MD 21010-5401

DISTRIBUTION UNLIMITED.

U.S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MD 21005-5055

The use of trade names in this document does not constitute an official endorsement or approval of the use of such commercial hardware or software. This document may not be cited for purposes of advertisement.

| REPORT DOCUMENTATION PAGE | | | Form Approved OMB No. 0704-0188 | |
|--|--|---|--|--|
| Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503. | | | | |
| 1. AGENCY USE ONLY (Leave blank) | 2. REPORT DATE September 1998 | 3. REPORT TYPE AND DATES COVERED Final (May 96 through Mar 98) | | |
| 4. TITLE AND SUBTITLE FINAL REPORT OF THE COALESCING TUBES TEST FOR OIL/WATER SEPARATOR (OWSs) | | | 5. FUNDING NUMBERS | |
| 6. AUTHOR(S) Klara, Paul C. | | | | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Commander U.S. Army Aberdeen Test Center ATTN: STEAC-SF-C Aberdeen Proving Ground, MD 21005-5059 | | | 8. PERFORMING ORGANIZATION REPORT NUMBER ATC-8115 | |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Commander U.S. Army Environmental Center ATTN: SFIM-AEC-ETT Aberdeen Proving Ground, MD 21010-5401 | | | 10. SPONSORING/MONITORING AGENCY REPORT NUMBER Same as Item 8 | |
| 11. SUPPLEMENTARY NOTES None | | | | |
| 12a. DISTRIBUTION AVAILABILITY STATEMENT Distribution unlimited. | | | 12b. DISTRIBUTION CODE | |
| 13. ABSTRACT (Maximum 200 words) The U.S. Army major commands (MACOMS) use thousands of gravity oil/water separators (OWSs) that currently require replacement or retrofit. This report summarizes an investigation to determine the effectiveness of vertical coalescing tubes (VCTs) as a retrofit to gravity OWSs. | | | | |
| 14. SUBJECT TERMS Oil Oleophilic Coalescing Tube Water Separator | | | 15. NUMBER OF PAGES | |
| | | | 16. PRICE CODE | |
| 17. SECURITY CLASSIFICATION OF REPORT Unclassified | 18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified | 19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified | 20. LIMITATION OF ABSTRACT SAR | |

TABLE OF CONTENTS

PAGE

SECTION 1. INTRODUCTION

| | | |
|-----|-------------------------|-----|
| 1.1 | SCOPE | 1-1 |
| 1.2 | BACKGROUND | 1-1 |
| 1.3 | CAVEATS | 1-2 |
| 1.4 | DEFINITIONS | 1-2 |
| 1.5 | EXECUTIVE SUMMARY | 1-2 |

SECTION 2. SUBTESTS

| | | |
|-----|---|-------|
| 2.1 | TOTAL PETROLEUM HYDROCARBONS (TPH) EFFLUENT | 2.1-1 |
| 2.2 | OIL AND GREASE EFFLUENT | 2.2-1 |
| 2.3 | pH ANALYSIS | 2.3-1 |
| 2.4 | TEMPERATURE EFFECT | 2.4-1 |

SECTION 3. APPENDIXES

| | | |
|---|--|-----|
| A | TEST CRITERIA | A-1 |
| B | OIL/WATER SEPARATOR (OWS) TEST PROCEDURE FOR COALESCING TUBE TEST | B-1 |
| C | TEST MATRIX AND WASTEWATER CONCENTRATIONS | C-1 |
| D | SPECIFIC GRAVITY AND VISCOSITY OF OILS | D-1 |
| E | REFERENCES | E-1 |
| F | ABBREVIATIONS | F-1 |
| G | DISTRIBUTION LIST | G-1 |

COALESCING TUBES TEST FOR GRAVITY OIL/WATER SEPARATORS (OWSs)

SECTION 1. INTRODUCTION

1.1 SCOPE

This report documents and analyzes test data acquired to determine the effectiveness of coalescing tubes for removal of oil in oil/water separators (OWSs). This report compares the performance of the same OWS both with and without oleophilic coalescing tubes.

The U.S. Army Environmental Center (AEC) is sponsoring this effort to examine retrofit technologies for existing OWSs on Army installations. The primary technology examined is the use of vertical, oleophilic coalescing tubes with oleophilic property to increase the effectiveness of existing OWS. This technology, if successful, will be implemented to reduce OWS upgrade costs when necessary to gain compliance with wastewater discharge regulations.

1.2 BACKGROUND

In order to maintain the operational readiness of the tactical vehicles, it is necessary to perform frequent washing of those vehicles or their components. The wastewater generated by these washing activities typically flows to a pretreatment structure, normally an OWS. Effluent from those separators must comply with wastewater quality limitations mandated by local, state, or federal regulation. The military is one of the largest owners of OWSs in the United States. Within the Army alone, the total number of separators currently owned is in the thousands.

In recent years, it has become obvious that many of the separators that the Department of Defense (DOD) has installed cannot meet current performance requirements. The poor performance of OWSs has promulgated DOD-wide efforts to upgrade existing systems by replacing them or installing a new system in series with the existing.

This project conducted testing by manufacturing wastewater of several different concentrations of oil and soil. This wastewater then flowed into the OWS and the effluent was measured for oil concentration. This test was conducted with the coalescing tubes installed and removed. The resulting effluent data provided a comparison of separator performance with and without the coalescing tubes. The wastewater influent and effluent were measured for oil concentration using Environmental Protection Agency (EPA) Method 1664, N-Hexane Extractable Material by Extraction and Gravimetry. This test yielded total petroleum hydrocarbon (TPH) concentration and oil and grease concentration. The wastewater temperature was measured using a thermocouple or gage to ensure consistence between tests. Consistent temperatures ensured that separator performance was not improved or degraded due to temperature variations. Finally, the pH was measured for every test to prevent acid cracking. When the pH of wastewater was less than 2, oil/water separation was enhanced. The goal was for a pH around 7, which is neutral.

Coalescing tubes are used to make small oil droplets called globules into larger globules. The larger globules float to the surface faster than smaller ones. In this manner, more oil is removed since the OWS length and wastewater horizontal velocity are fixed, but the vertical velocity is increased. There are several coalescing technologies available. This test examined vertical coalescing tubes (VCTs) since this type more easily lends itself to retrofit applications.

1.3 CAVEATS

Regulatory discharge limits, wastewater characteristics, and flow rates vary locally. However, they may be subject to change if subsequent legislation is enacted. The successful performance of coalescing tube oil/water separation technology does not assure selection or endorsement of that technology or manufacturer by DOD. Selections will or will not be made by the responsible technical authority for each system based on the specific regulatory and technical requirements, economics, and any other factors, as appropriate. Furthermore, this report provides test data and analysis of the oleophilic coalescing tube technology and does not endorse a specific manufacturer.

1.4 DEFINITIONS

The coalescing tube is a tube-shaped device that collects oil and improves oil movement to the water surface in an OWS. The coalescing tubes tested in this project were VCTs.

The effluent is the treated water exiting an OWS. This is water with the oil removed.

The influent is the untreated water entering an OWS. This is water before the oil is removed.

The OWS is a rectangular tank with baffles that may or may not have coalescing tubes. The purpose of this tank is to separate the oil from the influent water, utilizing the difference in specific gravity of oil and water and retention time.

The oleophilic is a property of the material used to make coalescing tubes. Oleophilic means oil attracting.

The specific gravity is the fractional comparison of a liquid's density with respect to the density of water.

1.5 EXECUTIVE SUMMARY

The VCTs tested in this project improved the separation of oil from water when installed in the OWS. In several instances, the coalescing tubes were the difference between the effluent water meeting the criteria for discharge into the sanitary sewer. In all but three test conditions, the coalescing tubes improved the oil separation from the wastewater.

The amount of dirt in the wastewater has a detrimental effect on the ability of the coalescing tubes to attract oil. In the three cases where oil/water separation was not improved, the quantity of dirt in the influent was a factor.

The VCTs and OWSs that use them are designed to remove oil from a 2000-mg/L influent concentration and produce effluent with 10 mg/L or less. This specification is stated by AFL Industries, a manufacturer of coalescing tube OWSs. This specification was not confirmed from the data obtained in this test. However, the polypropylene vertical coalescing tubes are susceptible to heat. Unfortunately, the coalescing tubes used in this test were subjected to high wastewater temperatures before this test. The original purpose, in addition to tube effectiveness, was to determine if age degraded performance. This was why a used OWS was tested. The coalescing tube performance degradation with time and usage was not obtained since the tubes were degraded due to high water temperatures.

When considering retrofit of existing OWSs, the existing OWS must have three chambers for the coalescing tubes to be effective. The first chamber is for settling of solids. The second chamber is for removal of oil. The third chamber is for polishing the effluent. The third chamber should also have a weir to help separate oil from the effluent pipe. In addition, the quantity of wastewater treated must be such that a wastewater velocity of 3 ft/min is not exceeded in the OWS. Velocities greater than 3 ft/min will wash the oil from the coalescing tubes and into the effluent stream.

The test data show that a 53-percent decrease in oil concentration in the effluent was realized using the coalescing tubes. This performance will possibly improve if nontemperature-degraded coalescing tubes are used.

2.1 TOTAL PETROLEUM HYDROCARBON (TPH) EFFLUENT

2.1.1 Objective

The objective of this test was to determine the TPH concentration in the water effluent for test conditions with and without oleophilic coalescing tubes installed in an OWS.

2.1.2 Criteria

For demonstration purposes the following criteria were used. Please be advised that regulatory limits vary by local jurisdiction:

a. The TPH effluent concentration shall not be more than 100 mg/L. Less than 100-mg/L effluent concentration permits discharge into the Aberdeen Proving Ground (APG) sanitary sewer as regulated by APGR 200-41.

b. The desired characteristic is for an effluent concentration of less than 15 mg/L. An effluent concentration of 15 mg/L or less permits discharge to the environment.

2.1.3 Test Procedure

The test conditions approximating typical wastewater generated by Army washracks, maintenance facilities, and depots were incorporated into a test matrix that included several wastewater flowrates. The wastewater influent conditions were derived from data collected by the U.S. Army Corps of Engineers (USACE) Construction Engineer Research Laboratory detailed in the report titled Characterization Of Oil/Water Separator Influent at U.S. Army Reserve Facilities. The data in this report characterize the wastewater influent from nine separate Army installations and five different facility types. Three wastewater concentrations were derived from the test data to provide a repeatable and reasonable approximation of field conditions for laboratory use. The first condition consisted of a concentration of 250 mg/L of TPH and 500 mg/L of total suspended solids (TSS). The second condition consisted of a concentration of 500 mg/L of TPH and 2000 mg/L of TSS. The third condition consisted of a concentration of 1500 mg/L of TPH and 6500 mg/L of TSS. The three wastewater conditions were tested at each flowrate. The wastewater flowrates were selected to meet, exceed, and be very low compared to the rated flowrate. The rated flowrate, 5 gallons per minute (gpm), was conducted to determine suitable function of the OWS as specified. The exceeded flowrate, 7 gpm, was conducted to determine if extra capacity was built into the system as a safety factor. The low flowrate, 1 gpm, test was conducted to approximate the actual use conditions where OWSs experience random usage. Typically, OWSs experience brief periods of heavy usage and extended periods of light usage. A fourth flowrate, 3 gpm, was added to prevent data gaps from adversely affecting the project. The test matrix is included in Appendix C.

Testing was conducted using a 5-gpm OWS with VCTs, commercially available from AFL Industries. Two 55-gallon drums were piped together and used to make the wastewater. The drums were filled with 100 gallons of water and the proper amounts of oil and soil were added to create the desired wastewater concentrations. The wastewater was continuously mixed using an electric drum mixer to ensure oil and solid dispersion. The outlets of these drums were piped to the OWS inlet. The outlet of the OWS was pumped into large holding tanks. The flow through the OWS was gravity feed with the flow controlled by a gate valve. This gate valve was calibrated to provide the required wastewater flowrates at specific settings. The wastewater, when judged thoroughly mixed with the oil and soil, was allowed to flow into the OWS. Water samples were taken from the influent and effluent of the OWS. This test was repeated under all wastewater concentrations and flowrates with and without the VCTs installed. This information provides a comparative performance of the VCT technology. The operational test procedure is included as Appendix B.

Samples taken at the influent and effluent of the OWS were analyzed in the chemistry laboratory for TPH. The TPH was conducted in accordance with EPA Method 1664, N-Hexane Extractable Material by Extraction and Gravimetry (Oil and Grease and Total Petroleum Hydrocarbons).

2.1.4 Data

Data were collected and tabulated and are presented in Appendix B, Tables B-2.1-1 through B-2.1-12 for the influent and effluent TPH and efficiency results of each flowrate and influent condition. These results were used to compute the average efficiency of the coalescing tube versus noncoalescing tube tests using influent data where the oil and solids were directly measured and then added to the wastewater-mixing drums. This analysis provided an average performance of the OWS. The data were also analyzed using the sampled influent TPH concentration relative to the sampled effluent TPH concentration. This analysis provided a specific measurement of the OWS performance at the time of sampling. The treatment performance of the OWSs is presented graphically in Appendix B, Figures B-2.1-1 through B-2.1-4. The average efficiency of the OWS with coalescing tubes is graphically compared to the same OWS without coalescing tubes in Appendix B, Figures B-2.1-5 through B-2.1-8. The specific efficiency of the OWS with coalescing tubes is graphically compared to the same OWS without coalescing tubes in Appendix B, Figures B-2.1-9 through B-2.1-12.

The concentrations for both the TPH and the oil and grease data are specified as mg/L. The OWS efficiency was computed using the formula as follows:

$$\text{Efficiency} = \frac{\text{Concentration In (mg/L)} - \text{Concentration Out (mg/L)}}{\text{Concentration In (mg/L)}}$$

2.1.5 Technical Analysis

The test data show that for every test condition and flowrate there was a significant decrease in TPH effluent when the OWS was fitted with the oleophilic coalescing tubes. There was also a corresponding improvement in efficiency when the OWS was fitted with oleophilic coalescing tubes. The data show that the coalescing tubes improved separation performance enough to meet the sanitary sewer criteria of 100 mg/L or less in 7 out of the 12 comparison cases. In three of the five test cases where the effluent did not meet the sanitary sewer criteria, the TPH and TSS levels were at the highest concentrations tested. The data from the remaining two cases show that the effluent met the sanitary sewer criteria both with and without coalescing tubes.

The test cases where the effluent met the sanitary sewer criteria with and without coalescing tubes installed occurred at low flowrates and low TPH and TSS concentrations. The effluent for both the 1- and 3-gpm tests show that the effluent was less than 100 mg/L during influents of 250 mg/L of TPH and 500 mg/L of TSS. These data indicate the flowrates and waste concentrations were sufficiently low that the OWS structure was able to remove sufficient oil via gravity to meet the criteria. However, while both effluent measurements for installed and removed coalescing tubes met the criteria, the effluent concentration with coalescing tubes installed was approximately one-half of the effluent concentration with the coalescing tubes removed. In this instance, the coalescing tubes improved the separation of oil and water, thereby producing a lower level of waste in the effluent.

The testing sequence went from low to high concentrations and from low to high flowrates. For example, the flowrates through the OWS were held constant while the oil and solid concentrations were increased from the low to the medium and then the high levels. When the one flowrate was completed, the flowrate was increased to the next increment while the oil and solid concentrations were reduced to the low level and the process was started again. This information explains why effluent concentrations were higher at low waste concentrations than medium concentrations for several test cases. During the 7-gpm effluent test cases with and without coalescing tubes, and the 5-gpm test case without the coalescing tubes installed, the low influent test case produced higher effluent TPH concentrations than the medium influent concentration test cases. These data suggest that the coalescing tubes retained oil when they were coated with dirt. The oil and dirt were released to the effluent when the influent oil and dirt concentrations were reduced. The coalescing tubes were coated with fine soil after several tests. Therefore, pretreatment settling of solids should be thoroughly considered in applications.

The wastewater generated for influent was mixed in one of the two 55-gallon drums. This wastewater was mixed using an electric, propeller type, drum mixer. While this method was the most practical available, it explains the difference between the average and specific influent concentrations. The mixing did not make the wastewater homogeneous.

The test plan required removal of the coalescing tubes after flowrates of 3, 5, and 7 gpm. This enabled testing to continue without coalescing tubes. The removed tubes showed adhered soil from the TSS. These tubes, when coated with the soil, did not operate as efficiently. For high concentrations of oil and soil, the coated tubes actually increased the TPH concentration in the effluent. This condition did not persist to the following test case and therefore is a short-term increase that returns to normal after time.

The data show that efficiency increases with increased influent concentrations. The bulk of the oil is more easily removed due to the greater quantity of larger oil droplets. These oil droplets are 100 microns and up. The larger oil droplets float to the surface faster than the smaller ones. In order to achieve lower effluent concentrations, the smaller oil droplets must be removed. The coalescing tubes are supposed to remove oil droplets down to 20 microns. The design criterion for the test OWS states a 10-mg/L effluent for a 2000-mg/L influent. While this is the specification, the OWS tested did not meet this standard. In fairness, however, the OWS tested was subjected to high-temperature water from a steam cleaner and possibly some harsh detergents. The detergents used will never be known, but the water temperature was definitely greater than 150 °F. The coalescing tube manufacturer states that exceeding this temperature will cause the tubes to swell and reduce their effectiveness. The test tubes were definitely swollen and exhibited reduced effectiveness.

2.2 OIL AND GREASE EFFLUENT

2.2.1 Objective

The objective of this test was to determine the oil and grease concentration in the water effluent for test conditions with and without oleophilic coalescing tubes installed in an OWS.

2.2.2 Criteria

For demonstration purposes the following criteria were used. Please be advised that regulatory limits vary by local jurisdiction:

a. The TPH effluent concentration shall not be more than 100 mg/L. Less than 100-mg/L effluent concentration permits discharge into the APG sanitary sewer as regulated by APGR 200-41.

b. The desired characteristic is for an effluent concentration of less than 15 mg/L. An effluent concentration of 15 mg/L or less permits discharge to the environment.

2.2.3 Test Procedure

The test conditions approximating typical wastewater generated by Army washracks, maintenance facilities, and depots were incorporated into a test matrix that included several wastewater flowrates. The wastewater influent conditions were derived from data collected by the USACE Construction Engineer Research Laboratory detailed in the report titled Characterization Of Oil/Water Separator Influent at U.S. Army Reserve Facilities. The data in this report characterize the wastewater influent from nine separate Army installations and five different facility types. Three wastewater concentrations were derived from the test data to provide a repeatable and reasonable approximation of field conditions for laboratory use. The first condition consisted of a concentration of 250 mg/L of TPH and 500 mg/L of TSS. The second condition consisted of a concentration of 500 mg/L of TPH and 2000 mg/L of TSS. The third condition consisted of a concentration of 1500 mg/L of TPH and 6500 mg/L of TSS. The three wastewater conditions were tested at each flowrate. The wastewater flowrates were selected to meet, exceed, and be very low compared to the rated flowrate. The rated flowrate, 5 gpm, was conducted to determine suitable function of the OWS as specified. The exceeded flowrate, 7 gpm, was conducted to determine if extra capacity was built into the system as a safety factor. The low flowrate, 1 gpm, test was conducted to approximate the actual use conditions where OWSs experience random usage. Typically, OWSs experience brief periods of heavy usage and extended periods of light usage. A fourth flowrate, 3 gpm, was added to prevent data gaps from adversely affecting the project. The test matrix is included in Appendix C.

Testing was conducted using a 5-gpm OWS with vertical coalescing tubes, commercially available from AFL Industries. Two 55-gallon drums were piped together and used to make the wastewater. The drums were filled with 100 gallons of water and the proper amounts of oil and soil were added to create the desired wastewater concentrations. The wastewater was continuously mixed using an electric drum mixer to ensure oil and solid dispersion. The outlets of these drums were piped to the OWS inlet. The outlet of the OWS was pumped into large holding tanks. The flow through the OWS was gravity feed with the flow controlled by a gate valve. This gate valve was calibrated to provide the required wastewater flowrates at specific settings. The wastewater, when judged thoroughly mixed with the oil and soil, was allowed to flow into the OWS. Water samples were taken from the influent and effluent of the OWS. This test was repeated under all wastewater concentrations and flowrates with and without the VCTs installed. This information provides a comparative performance of the VCT technology. The operational test procedure is included as Appendix B.

Samples taken at the influent and effluent of the OWS were analyzed in the chemistry laboratory for TPH. The TPH was conducted in accordance with EPA Method 1664, N-Hexane Extractable Material by Extraction and Gravimetry (Oil and Grease and Total Petroleum Hydrocarbons).

2.2.4 Data

Data were collected and tabulated and are presented in Appendix B, Tables B-2.2-1 through B-2.2-12 for the influent and effluent TPH and efficiency results of each flowrate and influent condition. These results were used to compute the average efficiency of the coalescing tube versus noncoalescing tube tests using influent data where the oil and solids were directly measured and then added to the wastewater-mixing drums. This analysis provided an average performance of the OWS. The data were also analyzed using the sampled influent TPH concentration relative to the sampled effluent TPH concentration. This analysis provided a specific measurement of the OWS performance at the time of sampling. The treatment performance of the OWSs is presented graphically in Appendix B, Figures B-2.2-1 through B-2.2-4. The average efficiency of the OWS with coalescing tubes is graphically compared to the same OWS without coalescing tubes in Appendix B, Figures B-2.2-5 through B-2.2-8. The specific efficiency of the OWS with coalescing tubes is graphically compared to the same OWS without coalescing tubes in Appendix B, Figures B-2.2-9 through B-2.2-12.

The concentrations for both the TPH and the oil and grease data are specified as mg/L. The OWS efficiency was computed using the formula as follows:

$$\text{Efficiency} = \frac{\text{Concentration In (mg/L)} - \text{Concentration Out (mg/L)}}{\text{Concentration In (mg/L)}}$$

2.2.5 Technical Analysis

The test data show that for every test condition and flowrate there was a significant decrease in the oil and grease effluent when the OWS was fitted with the oleophilic coalescing tubes. There was also a corresponding improvement in efficiency. The data show that the coalescing tubes improved separation performance enough to meet the sanitary sewer criterion of 100 mg/L or less in 5 out of 12 test cases. However, four of these test cases were sufficiently close to the criterion that they were within the error of the test method. This means that the data cannot be considered to have not met the criteria for these additional cases. If the data for these cases are considered satisfactory, the criteria are met for 9 out of 12 cases. The three remaining cases all occurred at the highest levels of soil concentration. This is further indication of the detrimental effect caused by dirt and emphasizes the need for pretreatment removal of dirt and regular cleaning maintenance of the coalescing tubes.

The oil and grease data show higher concentrations than the TPH data for the same sample. The sequence of laboratory analysis using EPA Method 1664, N-Hexane Extractable Material by Extraction and Gravimetry first removes the oil and grease from a sample and then the TPHs from what remains. This process removes the nonhydrocarbons from the oil, creating a common point of reference. This also explains why the oil and grease concentrations are higher than the TPH concentrations.

2.3 pH ANALYSIS

2.3.1 Objective

The objective of this test was to determine the acidity of the wastewater influent and water effluent from the OWS.

2.3.2 Criteria

a. The pH in the influent or effluent shall not be less than 2. When pH levels are less than 2 the acidity assists the separation of oil and water. This is called acid cracking.

b. The desired pH shall remain between 6 and 8. Since the neutral pH is 7 this criterion will ensure a consistently nonacidic, nonbasic solution.

2.3.3 Test Procedure

The test conditions approximating typical wastewater generated by Army washracks, maintenance facilities, and depots were incorporated into a test matrix that included several wastewater flowrates. The wastewater influent conditions were derived from data collected by the USACE Construction Engineer Research Laboratory. The data characterize the wastewater influent from nine separate Army installations and five different facility types. Three wastewater concentrations were derived from the test data to provide a repeatable and reasonable approximation of field conditions for laboratory use. The first condition consisted of a concentration of 250 mg/L of TPH and 500 mg/L of TSS. The second condition consisted of a concentration of 500 mg/L of TPH and 2000 mg/L of TSS. The third condition consisted of a concentration of 1500 mg/L of TPH and 6500 mg/L of TSS. The three wastewater conditions were tested at each flowrate. The wastewater flowrates were selected to meet, exceed, and be very low compared to the rated flowrate. The rated flowrate, 5 gpm, was conducted to determine suitable function of the OWS as specified. The exceeded flowrate, 7 gpm, was conducted to determine if extra capacity was built into the system as a safety factor. The low flowrate, 1 gpm, test was conducted to approximate the actual use conditions where OWSs experience random usage. Typically, OWSs experience brief periods of heavy usage and extended periods of light usage. A fourth flowrate, 3 gpm, was added to prevent data gaps from adversely affecting the project. The test matrix is included in Appendix C.

Testing was conducted using a 5-gpm OWS with VCTs, commercially available from AFL Industries. Two 55-gallon drums were piped together and used to make the wastewater. The drums were filled with 100 gallons of water and the proper amounts of oil and soil were added to create the desired wastewater concentrations. The wastewater was continuously mixed using an electric drum mixer to ensure oil and solid dispersion. The outlets of these drums were piped to the OWS inlet. The outlet of the OWS was pumped into large holding tanks. The flow through the OWS was gravity feed with the flow controlled by a gate valve. This gate valve was

calibrated to provide the required wastewater flowrates at specific settings. The wastewater, when judged thoroughly mixed with the oil and soil, was allowed to flow into the OWS. Water samples were taken from the influent and effluent of the OWS. This test was repeated under all wastewater concentrations and flowrates with and without the VCTs installed. This information provides a comparative performance of the VCT technology. The operational test procedure is included as Appendix B.

Samples taken at the influent and effluent of the OWS were analyzed in the chemistry laboratory for pH. The pH samples were analyzed using EPA Method 150.1.

2.3.4 Data

Data were collected and tabulated and are presented in Appendix B, Tables B-2.3-1 through B-2.3-4 for the influent and effluent pH of each flowrate and influent condition.

2.3-5 Technical Analysis

The test data show that for every test condition the pH never reached a value of 2. This ensured that acid cracking did not occur in any test conducted. While lowering the pH would help oil separation from water, the water's high acidity would require neutralizing before discharge could occur. The pH did fall below 6 for 5 of the 48 tests. All of these incidents occurred in the 7-gpm test condition. Since the pH criterion of between 6 and 8 is a desired criterion for consistency and the pH never went below 5.73, this is not considered significant and does not alter the test results. It is noted that all cases where the pH fell below 6 occurred with the high flowrate of 7 gpm and no coalescing tubes installed in the OWS. This reason for this is unknown. The pH criterion was met for all other tests conducted and there is no discernible relationship of pH to flowrate, TPH, or TSS concentration.

2.4 TEMPERATURE EFFECT

2.4.1 Objective

The objective of this test was to determine the temperature of the wastewater being processed in the OWS.

2.4.2 Criteria

The temperature of the wastewater in the OWS shall not exceed 70 °F during the testing at any concentration or flowrate. This criteria ensures that increased temperatures do not assist in the oil/water separation process.

2.4.3 Test Procedure

The temperature for all flowrate and waste concentration test conditions was measured using a thermocouple. This thermocouple was immersed in the wastewater-mixing drum and the temperature was recorded before the start of each test. The readings from the thermocouple became inaccurate with five tests remaining. A gauge-type thermometer was substituted for these tests.

2.4.4 Data

Temperature data were collected and tabulated and are presented in Appendix B, Tables B-2.4-1 through B-2.4-4 for each flowrate and influent condition.

2.4.5 Technical Analysis

The test data show that for every test condition the wastewater temperature never exceeded the desired criterion. Therefore, the wastewater temperature did not assist in the separation of the oil and water. Since the water used in the mixing of the wastewater came from the tap, was immediately mixed with the oil and solids, and immediately flowed into the OWS, this represents a reasonable actual-use condition. In motor pools, washracks, and depots, the cold tap water used to clean vehicles will flow into the OWS or sediment tank before increasing significantly in temperature.

| <u>Item</u> | <u>Applicable Source</u> | <u>Test Criteria</u> | <u>Subtest</u> | <u>Remarks</u> |
|-------------|-------------------------------------|--|----------------|----------------|
| 1 | Test Agency devised, TECOM approved | The TPH effluent concentration shall not be more than 100 mg/L. Less than 100 mg/L effluent concentration permits discharge into the APG sanitary sewer as regulated by APGR 200-41. | 2.1 | |
| 2 | Test Agency devised, TECOM approved | The desired characteristic is for an effluent concentration of less than 15 mg/L. An effluent concentration of 15 mg/L or less permits discharge to the environment. | 2.1 | |
| 3 | Test Agency devised, TECOM approved | The TPH effluent concentration shall not be more than 100 mg/L. Less than 100 mg/L effluent concentration permits discharge into the APG sanitary sewer as regulated by APGR 200-41. | 2.2 | |
| 4 | Test Agency devised, TECOM approved | The desired characteristic is for an effluent concentration of less than 15 mg/L. An effluent concentration of 15 mg/L or less permits discharge to the environment. | 2.2 | |
| 5 | Test Agency devised, TECOM approved | The pH in the influent or effluent not be less than 2. When pH levels are less than 2 the acidity assists in separation of oil and water. This is called acid cracking. | 2.3 | |
| 6 | Test Agency devised, TECOM approved | The desired pH shall remain between 6 and 8. Since the neutral pH is 7 this criteria will ensure a consistently nonacidic, nonbasic solution. | 2.3 | |

| Item | Applicable Source | Test Criteria | Subtest | Remarks |
|------|-------------------------------------|---|---------|---------|
| 7 | Test Agency devised, TECOM approved | The temperature of the wastewater in the OWS shall not exceed 70°F during the testing at any concentration or flowrate. | 2.4 | |

**APPENDIX B. OIL/WATER SEPARATOR (OWS) TEST PROCEDURE FOR
COALESCING TUBE TEST**

1. Assemble test fixture and check for leaks. Fixture should have one or more supply tanks, the OWS, and outlet tanks for waste oil and effluent water.
2. Ensure that coalescing tubes have been cleaned without the use of detergents and are being used if desired.
3. Fill water drums to the desired level of 100 gallons (378.5 liters).
4. Put in the proper concentration of waste oil for 100 gallons of wastewater in accordance with the following chart:

| Desired Concentration, mg/L | Total Oil | | Specific Gravity | Total Oil, mL |
|-----------------------------|-----------|-------|------------------|---------------|
| | mg | g | | |
| 250 | 94,635 | 94.6 | 0.8874 | 107 |
| 500 | 189,270 | 189.3 | 0.8874 | 213 |
| 1500 | 567,810 | 567.8 | 0.8874 | 640 |

1000 mg = 1 cc.
 1 cc = 1 mL.
 1000 mg = 1 mL.

Viscosity of 15W-40 oil at 100 °C was measured at 10.3 centistokes.

5. Put in the proper concentration of soil for 100 gallons of wastewater in accordance with the following chart:

| Desired Concentration, mg/L | Total Soil | | |
|-----------------------------|------------|---------|------|
| | mg | g | lb |
| 500 | 189,250 | 189.3 | 0.42 |
| 2000 | 757,080 | 757.1 | 1.67 |
| 6500 | 2,460,510 | 2,460.5 | 5.42 |

6. Stir the mixture thoroughly until the oil and soil are evenly dispersed in the water.
7. The wastewater mixture is not to set for an extended period of time before the test is conducted. This prevents the settleable solids from settling in the mixing tanks and requires the OWS grit basin to separate any solids.

8. Adjust the flow control valve to the desired setting in accordance with the following chart:

| Flowrate, gpm | Valve Setting |
|------------------|----------------|
| 1 | 9/16 |
| 3 | 7/8 |
| 5 | 1 1/16 - 1 1/8 |
| 7 | 1 1/4 |

9. Record the temperature of the wastewater in the supply drums.
10. Open the gate valve, start the wastewater flow into the OWS, and record the start time.
11. Wait approximately 3 minutes, then open the influent sample valve, and fill a 1-liter sample bottle and a 100-milliliter sample bottle.
12. When all the wastewater has finished flowing from the supply drums, close the gate valve.
13. Stir the water in the effluent tank and fill 1-liter and 100-milliliter sample bottles.
14. Label the sample with the following information:
 - Trial Number.
 - Test Oil Concentration.
 - Test Soil Concentration.
 - Wastewater Flowrate.
 - Influent or Effluent.
 - Date of Test.
15. Record the stop time and determine the time in minutes that the wastewater flows into the OWS.
16. Remove wastewater from the OWS and wash down the supply drums with water. Store the wastewater in holding tank.
17. Repeat the test for the next trial condition.

TABLE B-2.1-1. TOTAL PETROLEUM HYDROCARBON EFFLUENT AND AVERAGE EFFICIENCY FOR COALESCING TUBE OWS

| 1-gpm Flowrate | Influent | | |
|---------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| TPH Tubes (mg/L) | 47.8 | 80.0 | 140.3 |
| TPH No Tubes (mg/L) | 98.2 | 137.3 | 267.0 |
| Efficiency Tubes | 0.809 | 0.840 | 0.907 |
| Efficiency No Tubes | 0.607 | 0.725 | 0.822 |

TABLE B-2.1-2. TOTAL PETROLEUM HYDROCARBON EFFLUENT AND AVERAGE EFFICIENCY FOR COALESCING TUBE OWS

| 3-gpm Flowrate | Influent | | |
|---------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| TPH Tubes (mg/L) | 33.9 | 46.8 | 284.3 |
| TPH No Tubes (mg/L) | 59.2 | 133.3 | 378.5 |
| Efficiency Tubes | 0.864 | 0.906 | 0.811 |
| Efficiency No Tubes | 0.763 | 0.733 | 0.748 |

TABLE B-2.1-3. TOTAL PETROLEUM HYDROCARBON EFFLUENT AND AVERAGE EFFICIENCY FOR COALESCING TUBE OWS

| 5-gpm Flowrate | Influent | | |
|---------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| TPH Tubes (mg/L) | 35.3 | 55.8 | 72.1 |
| TPH No Tubes (mg/L) | 166.1 | 124.5 | 327.4 |
| Efficiency Tubes | 0.859 | 0.887 | 0.952 |
| Efficiency No Tubes | 0.336 | 0.751 | 0.782 |

TABLE B-2.1-4. TOTAL PETROLEUM HYDROCARBON EFFLUENT AND AVERAGE EFFICIENCY FOR COALESCING TUBE OWS

| 7-gpm Flowrate | Influent | | |
|---------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| TPH Tubes (mg/L) | 85.5 | 78.5 | 127.2 |
| TPH No Tubes (mg/L) | 283.7 | 240.5 | 451.1 |
| Efficiency Tubes | 0.658 | 0.843 | 0.915 |
| Efficiency No Tubes | -0.135 | 0.519 | 0.699 |

Note: Target level for effluent is less than 100 mg/L.

TABLE B-2.1-5. TOTAL PETROLEUM HYDROCARBON INFLUENT, EFFLUENT, AND SPECIFIC EFFICIENCY FOR COALESCING TUBE OWS

| 1-gpm Flowrate with Coalescing Tubes | | | |
|--------------------------------------|-------|-------|-------|
| Influent TPH (mg/L) | 407.5 | 890.6 | 640.3 |
| Effluent TPH (mg/L) | 47.8 | 80.0 | 140.3 |
| Efficiency | 0.883 | 0.910 | 0.781 |

TABLE B-2.1-6. TOTAL PETROLEUM HYDROCARBON INFLUENT, EFFLUENT, AND SPECIFIC EFFICIENCY FOR COALESCING TUBE OWS

| 1-gpm Flowrate without Coalescing Tubes | | | |
|---|-------|-------|-------|
| Influent TPH (mg/L) | 340.4 | 609.3 | 695.3 |
| Effluent TPH (mg/L) | 98.2 | 137.3 | 267.0 |
| Efficiency | 0.712 | 0.775 | 0.616 |

TABLE B-2.1-7. TOTAL PETROLEUM HYDROCARBON INFLUENT, EFFLUENT, AND SPECIFIC EFFICIENCY FOR COALESCING TUBE OWS

| 3-gpm Flowrate with Coalescing Tubes | | | |
|--------------------------------------|-------|-------|-------|
| Influent TPH (mg/L) | 351.5 | 282.6 | 876.3 |
| Effluent TPH (mg/L) | 33.9 | 46.8 | 284.3 |
| Efficiency | 0.904 | 0.834 | 0.676 |

TABLE B-2.1-8. TOTAL PETROLEUM HYDROCARBON INFLUENT, EFFLUENT, AND SPECIFIC EFFICIENCY FOR COALESCING TUBE OWS

| 3-gpm Flowrate without Coalescing Tubes | | | |
|---|-------|-------|-------|
| Influent TPH (mg/L) | 119.8 | 427.7 | 906.2 |
| Effluent TPH (mg/L) | 59.2 | 133.3 | 378.5 |
| Efficiency | 0.506 | 0.688 | 0.582 |

Note: Target level for effluent is less than 100 mg/L.

TABLE B-2.1-9. TOTAL PETROLEUM HYDROCARBON INFLUENT, EFFLUENT, AND SPECIFIC EFFICIENCY FOR COALESCING TUBE OWS

| 5-gpm Flowrate with Coalescing Tubes | | | |
|--------------------------------------|-------|-------|-------|
| Influent TPH (mg/L) | 90.8 | 334.1 | 768.3 |
| Effluent TPH (mg/L) | 35.3 | 55.8 | 72.1 |
| Efficiency | 0.611 | 0.833 | 0.906 |

TABLE B-2.1-10. TOTAL PETROLEUM HYDROCARBON INFLUENT, EFFLUENT, AND SPECIFIC EFFICIENCY FOR COALESCING TUBE OWS

| 5 gpm Flowrate without Coalescing Tubes | | | |
|---|-------|-------|-------|
| Influent TPH (mg/L) | 271.2 | 309.9 | 846.3 |
| Effluent TPH (mg/L) | 166.1 | 124.5 | 327.4 |
| Efficiency | 0.388 | 0.598 | 0.613 |

TABLE B-2.1-11. TOTAL PETROLEUM HYDROCARBON INFLUENT, EFFLUENT, AND SPECIFIC EFFICIENCY FOR COALESCING TUBE OWS

| 7-gpm Flowrate with Coalescing Tubes | | | |
|--------------------------------------|-------|-------|-------|
| Influent TPH (mg/L) | 316.8 | 527.6 | 519.4 |
| Effluent TPH (mg/L) | 85.5 | 78.5 | 127.2 |
| Efficiency | 0.730 | 0.851 | 0.755 |

TABLE B-2.1-12. TOTAL PETROLEUM HYDROCARBON INFLUENT, EFFLUENT AND SPECIFIC EFFICIENCY FOR COALESCING TUBE OWS

| 7-gpm Flowrate without Coalescing Tubes | | | |
|---|-------|-------|-------|
| Influent TPH (mg/L) | 416.8 | 995.9 | 723.9 |
| Effluent TPH (mg/L) | 283.7 | 240.5 | 451.1 |
| Efficiency | 0.319 | 0.759 | 0.377 |

Note: Target level for effluent is less than 100 mg/L.

Oil / Water Separator Effluent (1 GPM)

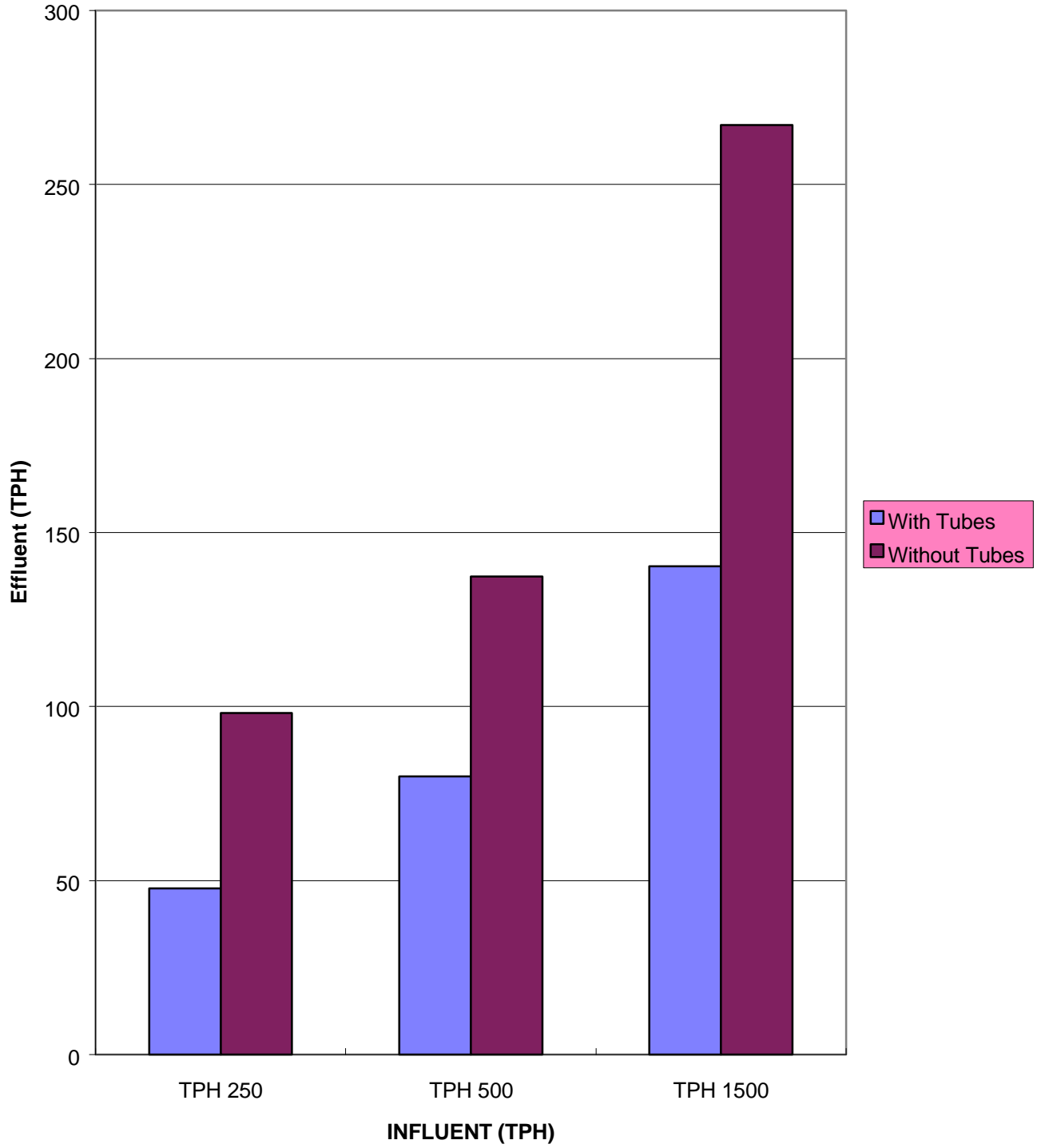


Figure B-2.1-1. OWS effluent (1 gpm).

Oil / Water Separator Effluent (3 GPM)

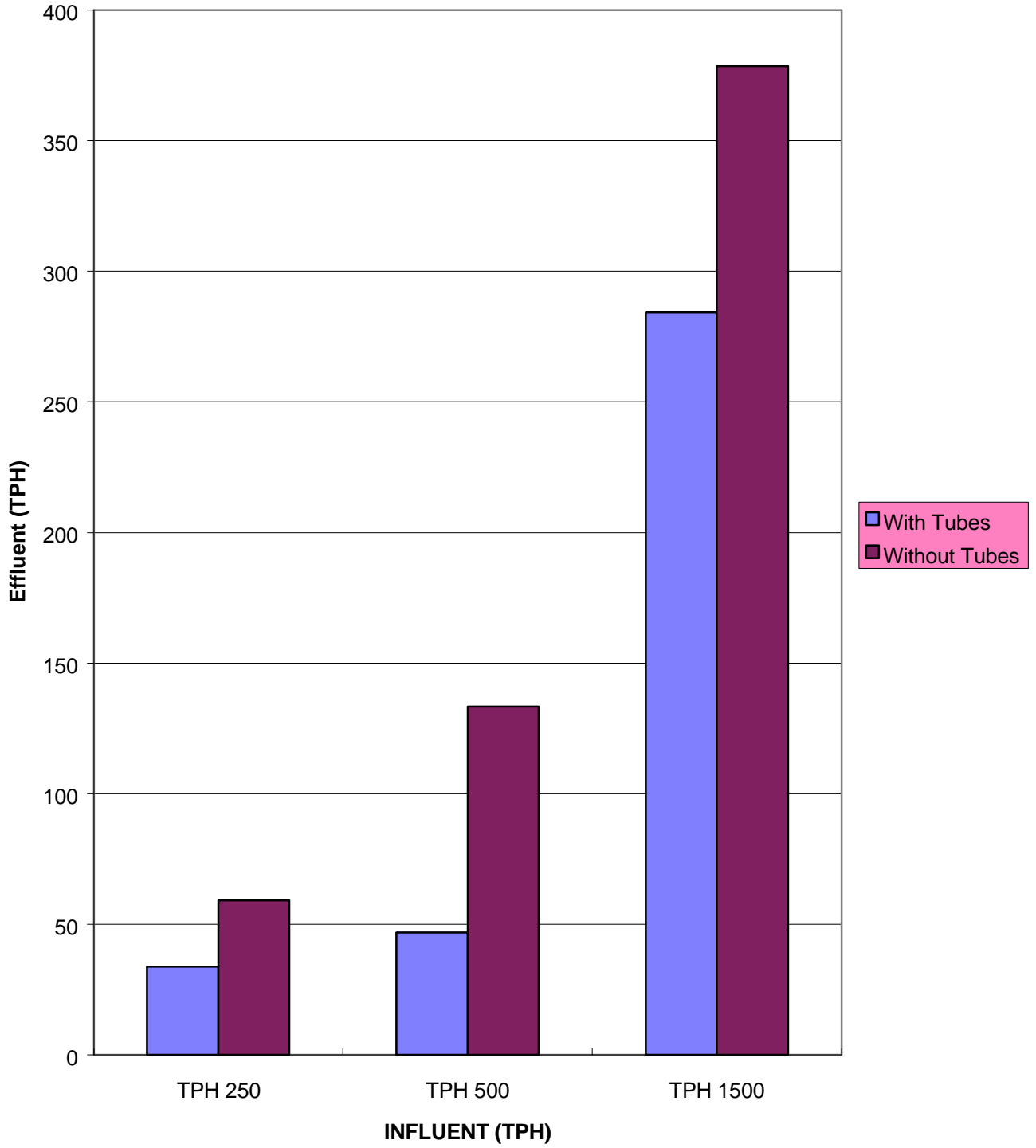


Figure B-2.1-2. OWS effluent (3 gpm).

Oil / Water Separator Effluent (5 GPM)

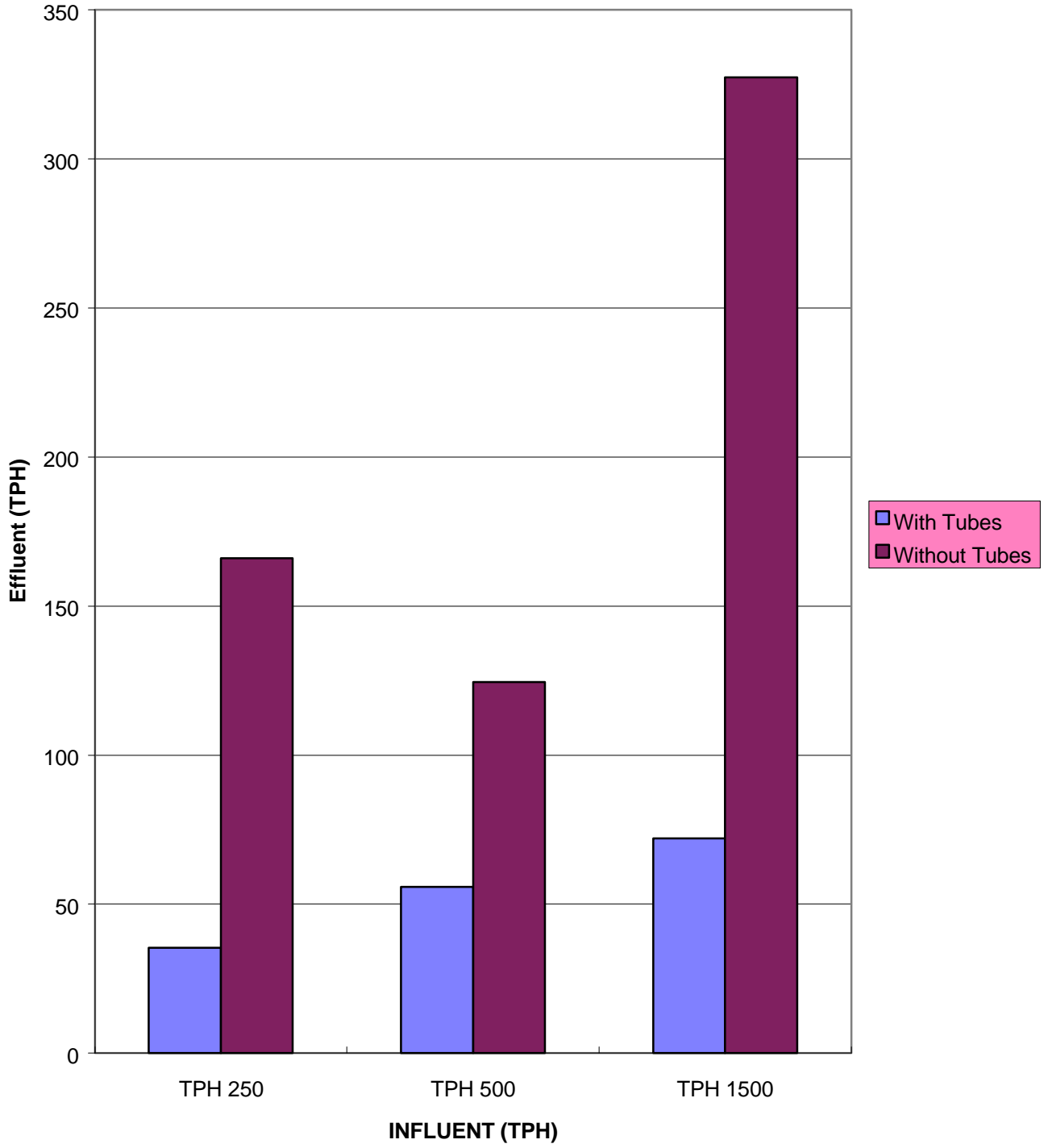


Figure B-2.1-3. OWS effluent (5 gpm).

Oil / Water Separator Effluent (7 GPM)

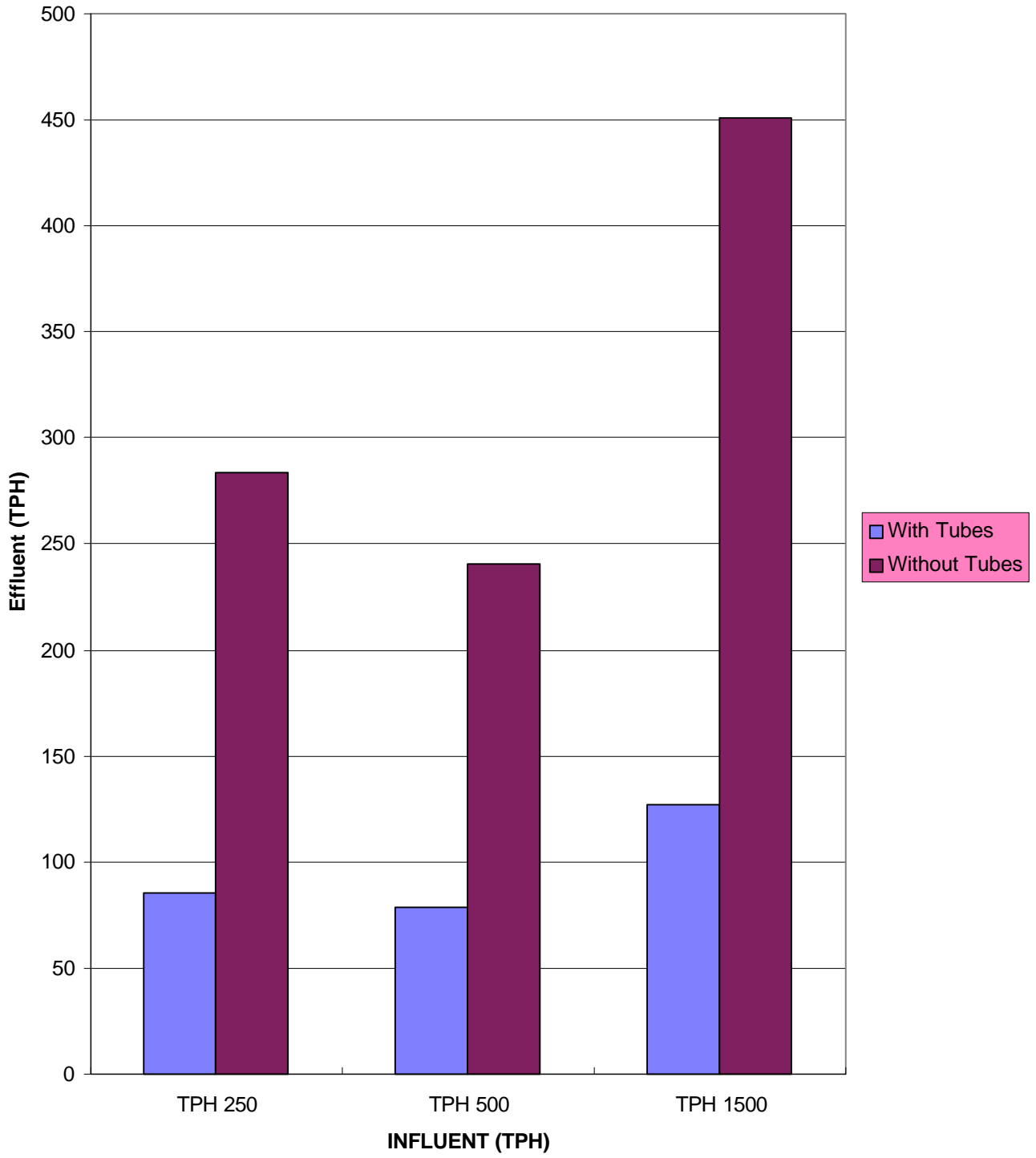


Figure B-2.1-4. OWS effluent (7 gpm).

Average Oil / Water Separator Efficiency (1 GPM)

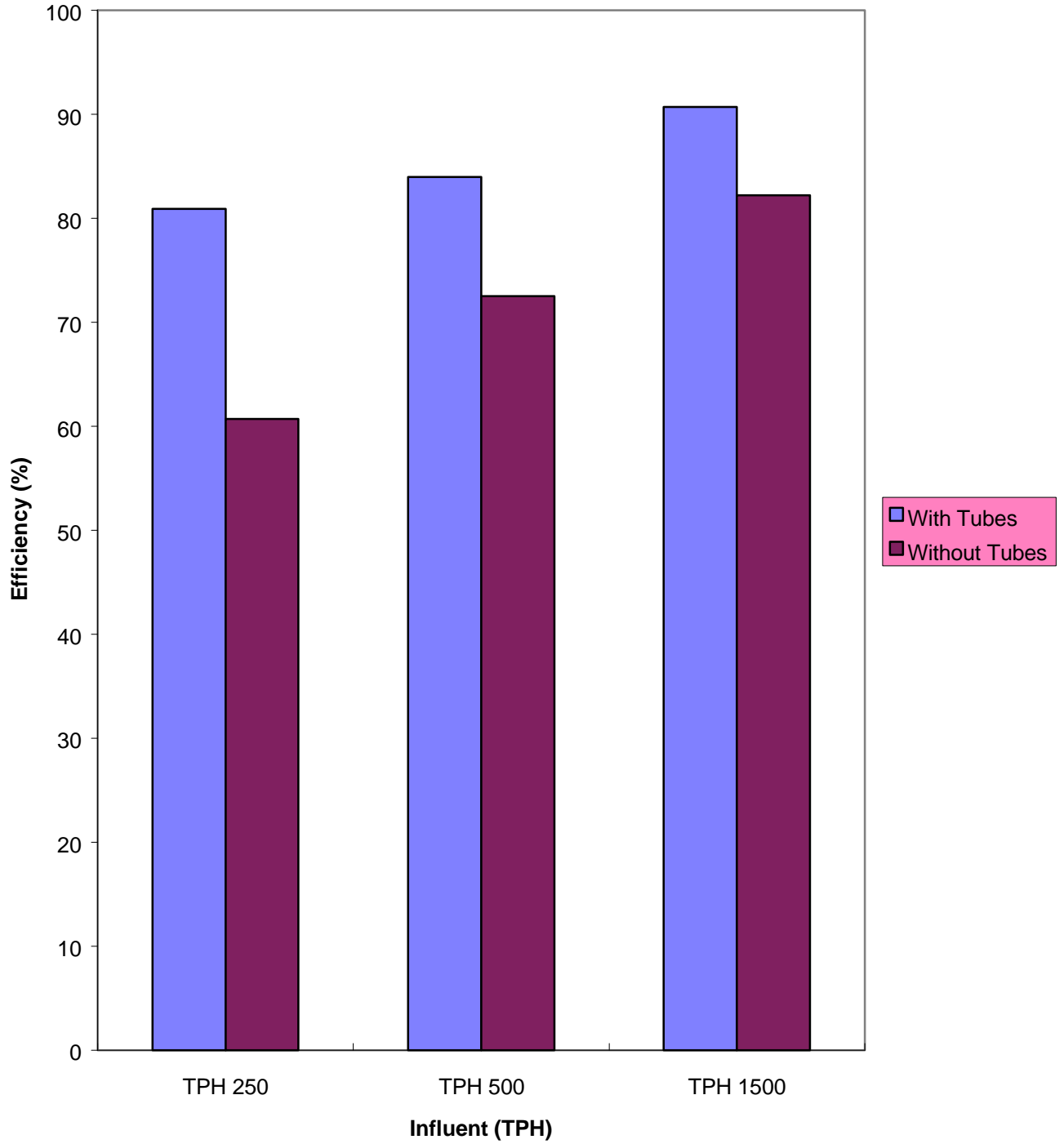


Figure B-2.1-5. Average OWS efficiency (1 gpm).

Average Oil / Water Separator Efficiency (3 GPM)

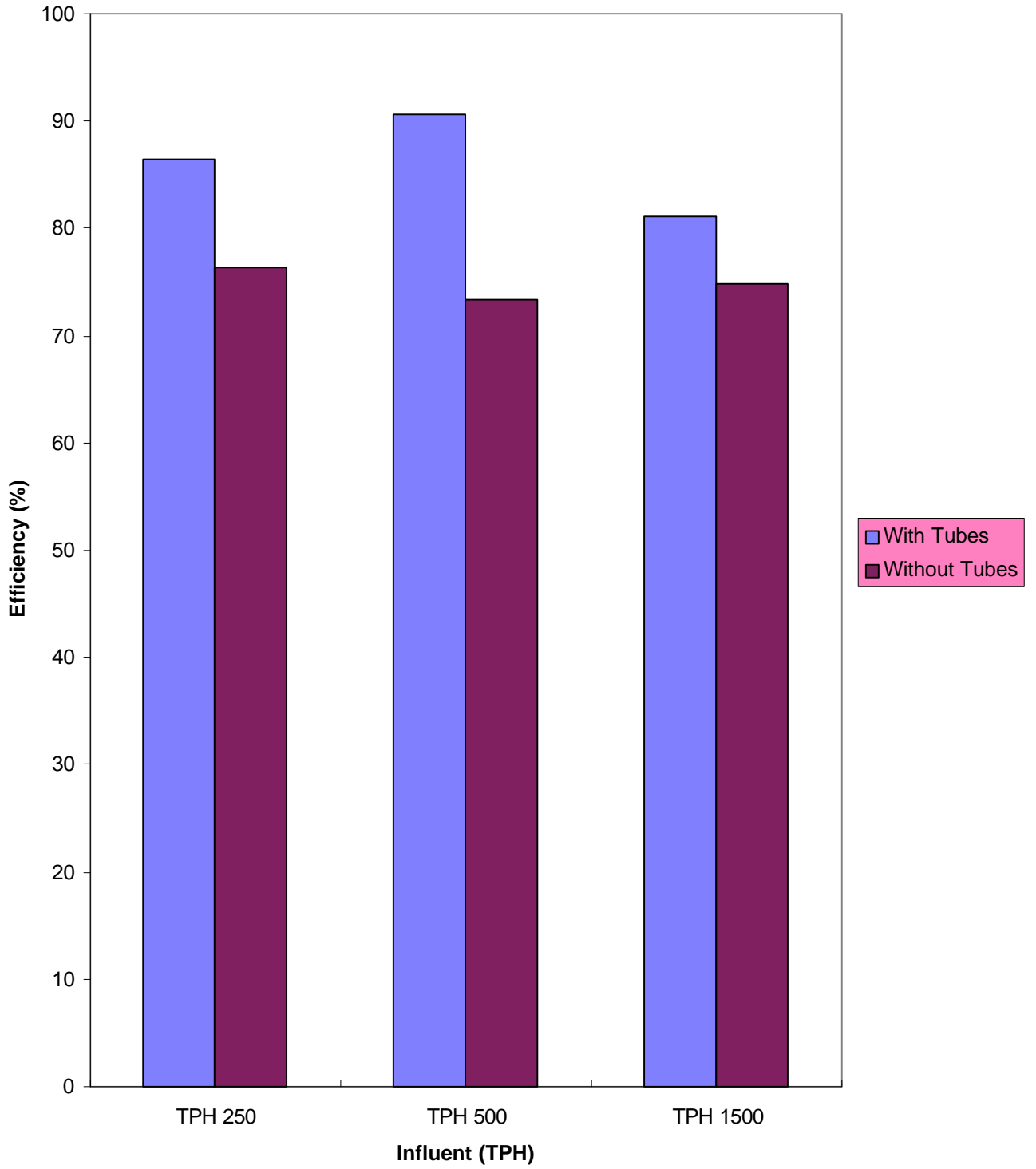


Figure B-2.1-6. Average OWS efficiency (3 gpm).

Average Oil / Water Separator Efficiency (5 GPM)

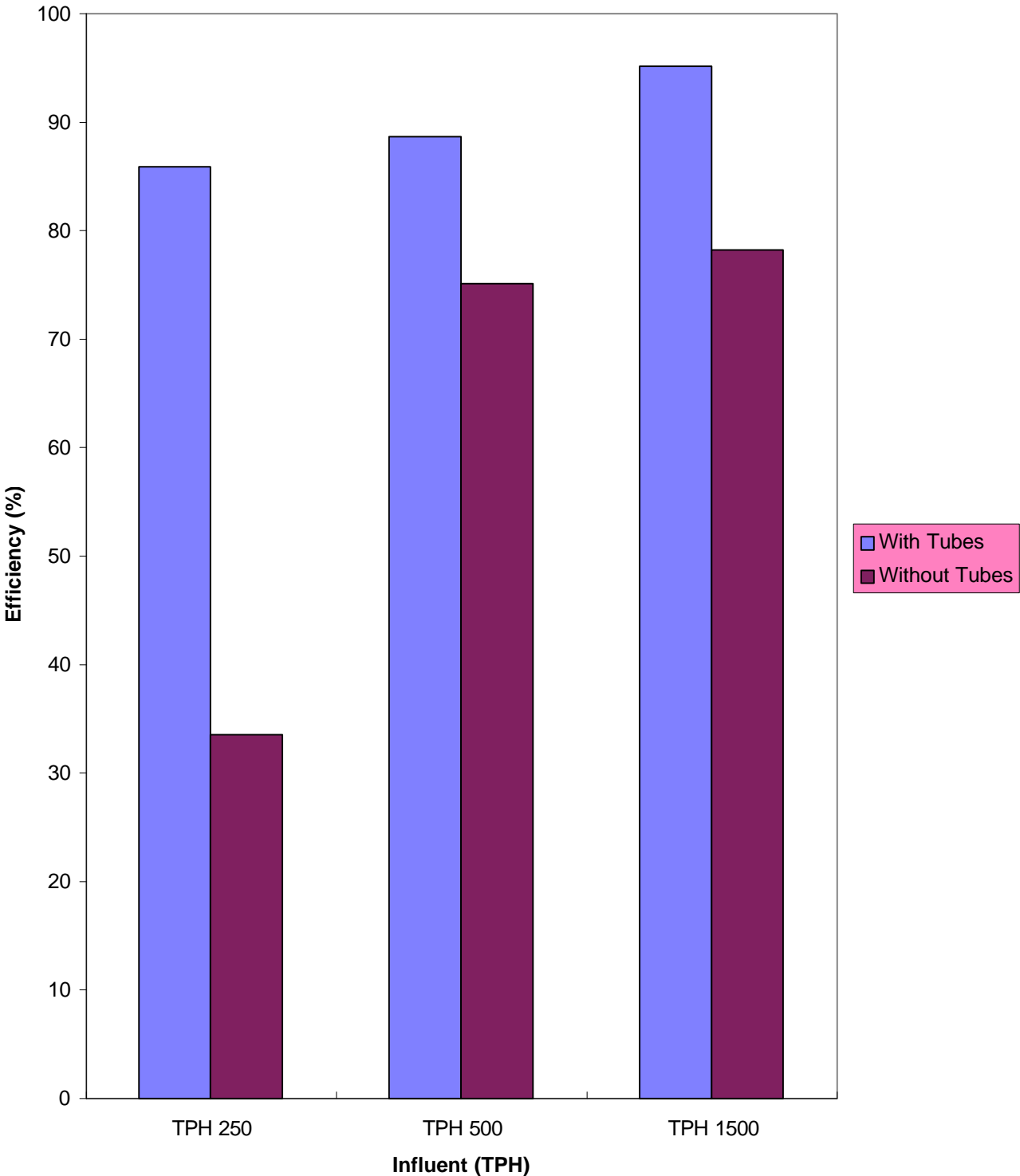


Figure B-2.1-7. Average OWS efficiency (5 gpm).

Average Oil / Water Separator Efficiency (7 GPM)

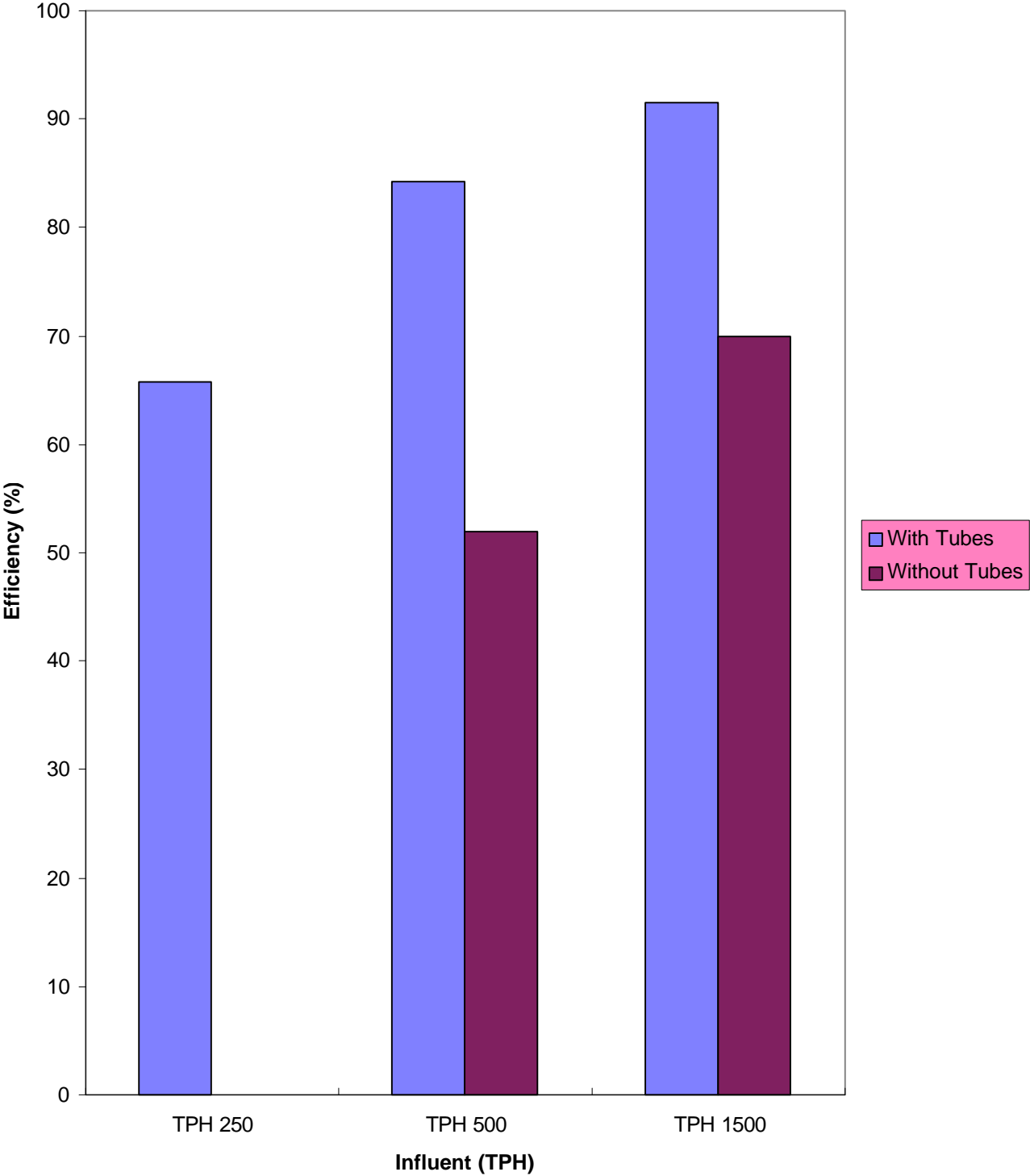


Figure B-2.1-8. Average OWS efficiency (7 gpm).

Specific Oil / Water Separator Efficiency (1 GPM)

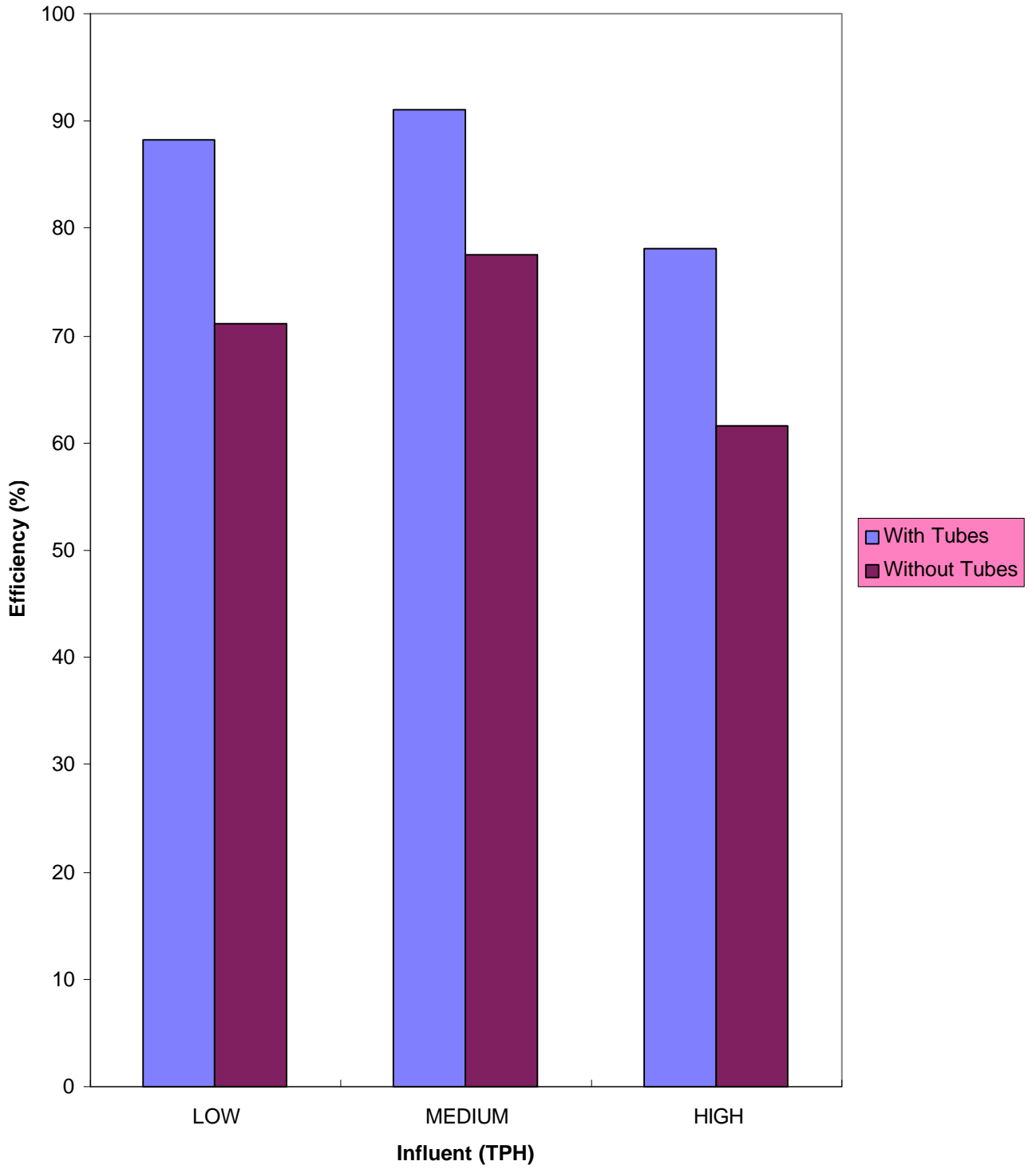


Figure B-2.1-9. Specific OWS efficiency (1 gpm).

Specific Oil / Water Separator Efficiency (3 GPM)

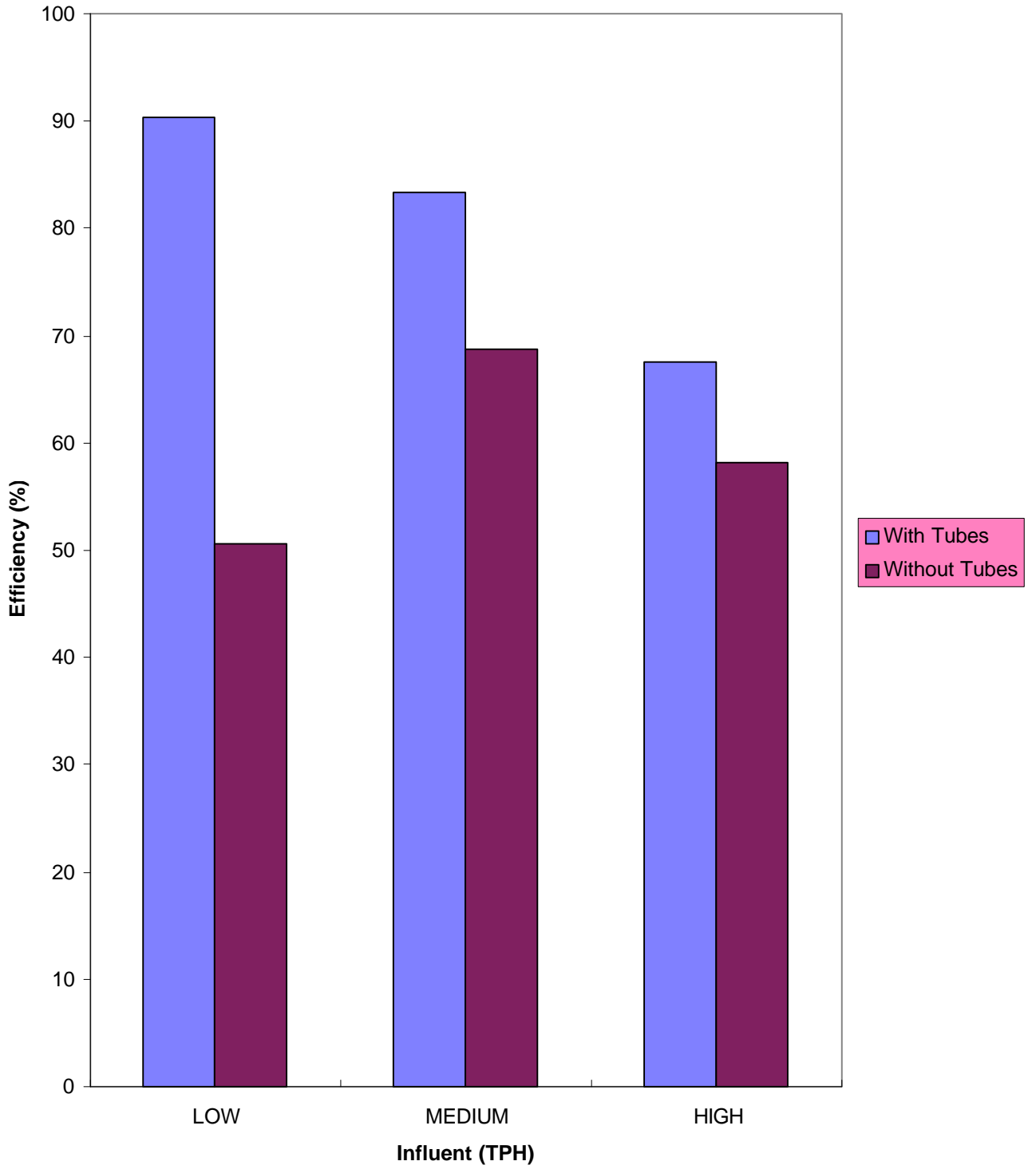


Figure B-2.1-10. Specific OWS efficiency (3 gpm).

Specific Oil / Water Separator Efficiency (5 GPM)

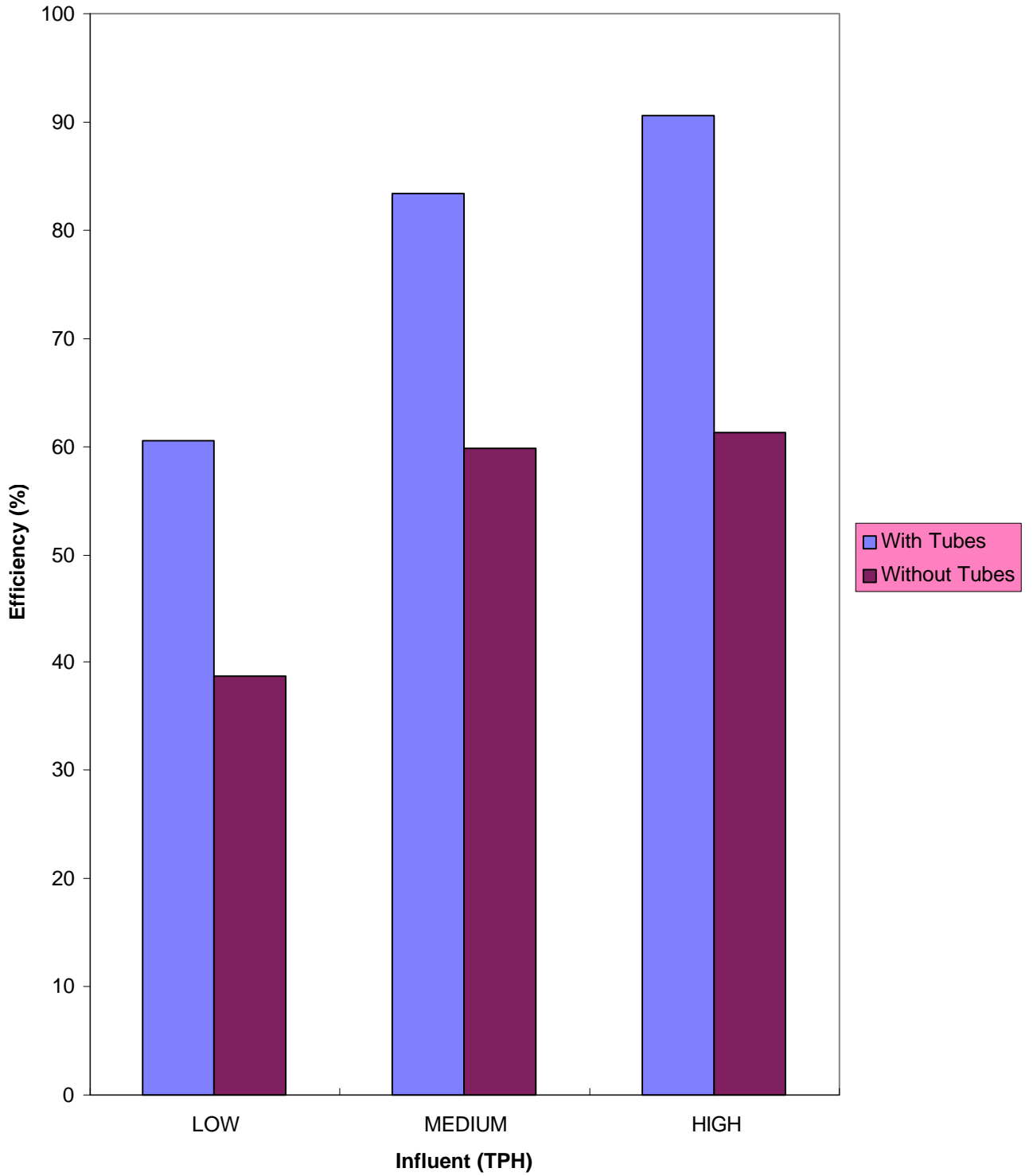


Figure B-2.1-11. Specific OWS efficiency (5 gpm).

Specific Oil / Water Separator Efficiency (7 GPM)

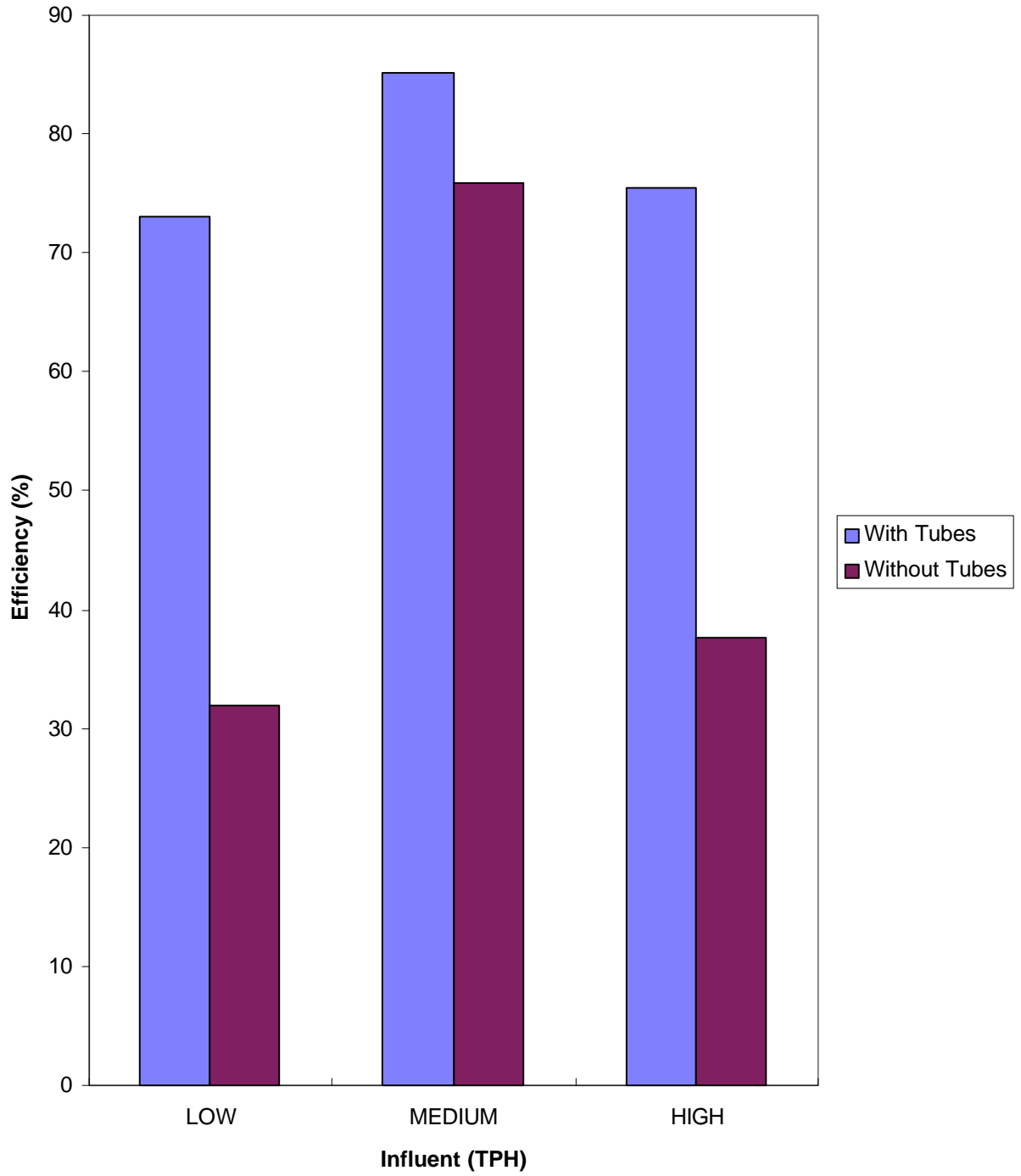


Figure B-2.1-12. Specific OWS efficiency (7 gpm).

B-2.1-15

(Page B-2.1-16 Blank)

TABLE B-2.2-1. OIL AND GREASE EFFLUENT AND AVERAGE EFFICIENCY FOR COALESCING TUBE OWS

| 1-gpm Flowrate | Influent | | |
|---------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| O&G Tubes (mg/L) | 102.8 | 76.0 | 185.8 |
| O&G No Tubes (mg/L) | 159.2 | 201.5 | 438.2 |
| Efficiency Tubes | 0.589 | 0.848 | 0.876 |
| Efficiency No Tubes | 0.363 | 0.597 | 0.708 |

O&G = Oil and grease.

TABLE B-2.2-2. OIL AND GREASE EFFLUENT AND AVERAGE EFFICIENCY FOR COALESCING TUBE OWS

| 3-gpm Flowrate | Influent | | |
|---------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| O&G Tubes (mg/L) | 44.0 | 59.9 | 392.9 |
| O&G No Tubes (mg/L) | 82.4 | 215.6 | 705.9 |
| Efficiency Tubes | 0.824 | 0.880 | 0.738 |
| Efficiency No Tubes | 0.670 | 0.569 | 0.529 |

TABLE B-2.2-3. OIL AND GREASE EFFLUENT AND AVERAGE EFFICIENCY FOR COALESCING TUBE OWS

| 5-gpm Flowrate | Influent | | |
|---------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| O&G Tubes (mg/L) | 48.6 | 73.0 | 102.9 |
| O&G No Tubes (mg/L) | 275.9 | 198.5 | 505.8 |
| Efficiency Tubes | 0.806 | 0.854 | 0.931 |
| Efficiency No Tubes | -0.104 | 0.603 | 0.663 |

TABLE B-2.2-4. OIL AND GREASE EFFLUENT AND AVERAGE EFFICIENCY FOR COALESCING TUBE OWS

| 7-gpm Flowrate | Influent | | |
|---------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| O&G Tubes (mg/L) | 120.6 | 112.2 | 184.3 |
| O&G No Tubes (mg/L) | 408.8 | 373.9 | 755.3 |
| Efficiency Tubes | 0.517 | 0.776 | 0.877 |
| Efficiency No Tubes | -0.635 | 0.252 | 0.497 |

TABLE B-2.2-5. OIL AND GREASE INFLUENT,
EFFLUENT, AND SPECIFIC EFFICIENCY
FOR COALESCING TUBE OWS

| 1-gpm Flowrate with Coalescing Tubes | | | |
|--------------------------------------|-------|--------|-------|
| Influent O&G (mg/L) | 569.0 | 1695.2 | 923.7 |
| Effluent O&G (mg/L) | 102.8 | 76.0 | 185.8 |
| Efficiency | 0.819 | 0.955 | 0.799 |

TABLE B-2.2-6. OIL AND GREASE INFLUENT,
EFFLUENT, AND SPECIFIC EFFICIENCY
FOR COALESCING TUBE OWS

| 1-gpm Flowrate without Coalescing Tubes | | | |
|---|-------|-------|--------|
| Influent O&G (mg/L) | 582.3 | 923.7 | 1005.6 |
| Effluent O&G (mg/L) | 159.2 | 201.5 | 438.2 |
| Efficiency | 0.727 | 0.782 | 0.564 |

TABLE B-2.2-7. OIL AND GREASE INFLUENT,
EFFLUENT, AND SPECIFIC EFFICIENCY
FOR COALESCING TUBE OWS

| 3-gpm Flowrate with Coalescing Tubes | | | |
|--------------------------------------|-------|-------|--------|
| Influent O&G (mg/L) | 464.7 | 392.4 | 1148.9 |
| Effluent O&G (mg/L) | 44.0 | 59.9 | 392.9 |
| Efficiency | 0.905 | 0.847 | 0.658 |

TABLE B-2.2-8. OIL AND GREASE INFLUENT,
EFFLUENT, AND SPECIFIC EFFICIENCY
FOR COALESCING TUBE OWS

| 3-gpm Flowrate without Coalescing Tubes | | | |
|---|-------|-------|--------|
| Influent O&G (mg/L) | 153.3 | 711.5 | 1563.6 |
| Effluent O&G (mg/L) | 82.4 | 215.6 | 705.9 |
| Efficiency | 0.463 | 0.697 | 0.549 |

TABLE B-2.2-9. OIL AND GREASE INFLUENT, EFFLUENT, AND SPECIFIC EFFICIENCY FOR COALESCING TUBE OWS

| 5-gpm Flowrate with Coalescing Tubes | | | |
|--------------------------------------|-------|-------|--------|
| Influent O&G (mg/L) | 123.4 | 481.3 | 1187.9 |
| Effluent O&G (mg/L) | 48.6 | 73.0 | 102.9 |
| Efficiency | 0.606 | 0.848 | 0.913 |

TABLE B-2.2-10. OIL AND GREASE INFLUENT, EFFLUENT, AND SPECIFIC EFFICIENCY FOR COALESCING TUBE OWS

| 5-gpm Flowrate without Coalescing Tubes | | | |
|---|-------|-------|--------|
| Influent O&G (mg/L) | 370.2 | 456.3 | 1390.9 |
| Effluent O&G (mg/L) | 275.9 | 198.5 | 505.8 |
| Efficiency | 0.255 | 0.565 | 0.636 |

TABLE B-2.2-11. OIL AND GREASE INFLUENT, EFFLUENT, AND SPECIFIC EFFICIENCY FOR COALESCING TUBE OWS

| 7-gpm Flowrate with Coalescing Tubes | | | |
|--------------------------------------|-------|-------|-------|
| Influent O&G (mg/L) | 528.4 | 785.2 | 879.4 |
| Effluent O&G (mg/L) | 120.6 | 112.2 | 184.3 |
| Efficiency | 0.772 | 0.857 | 0.790 |

TABLE B-2.2-12. OIL AND GREASE INFLUENT, EFFLUENT, AND SPECIFIC EFFICIENCY FOR COALESCING TUBE OWS

| 7-gpm Flowrate without Coalescing Tubes | | | |
|---|-------|--------|--------|
| Influent O&G (mg/L) | 655.3 | 1743.3 | 1297.3 |
| Effluent O&G (mg/L) | 408.8 | 373.9 | 755.3 |
| Efficiency | 0.376 | 0.786 | 0.418 |

**Oil / Water Separator Effluent (1 GPM)
Oil and Grease**

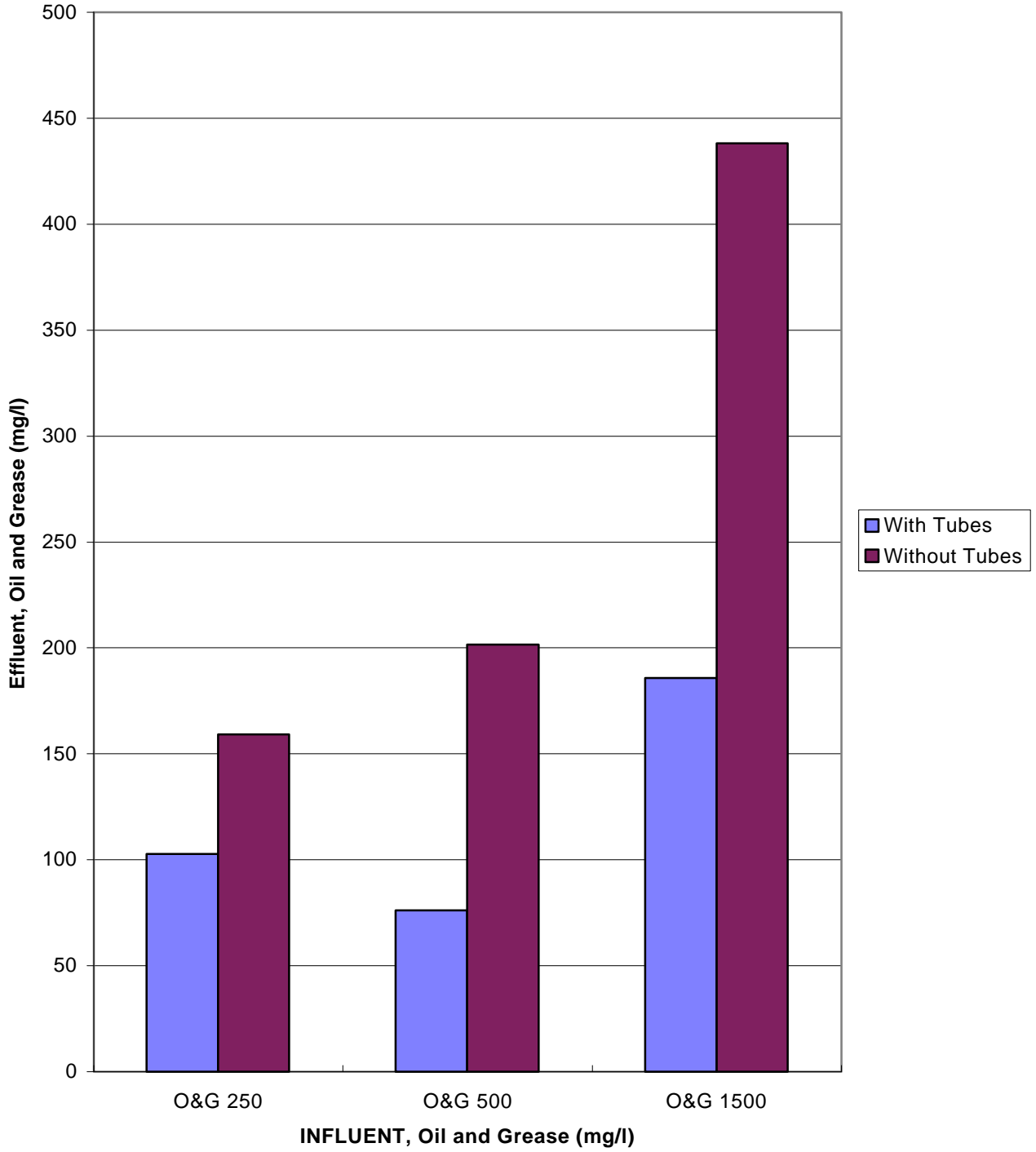


Figure B-2.2-1. OWS effluent (1 gpm), oil and grease.

**Oil / Water Separator Effluent (3 GPM)
Oil and Grease**

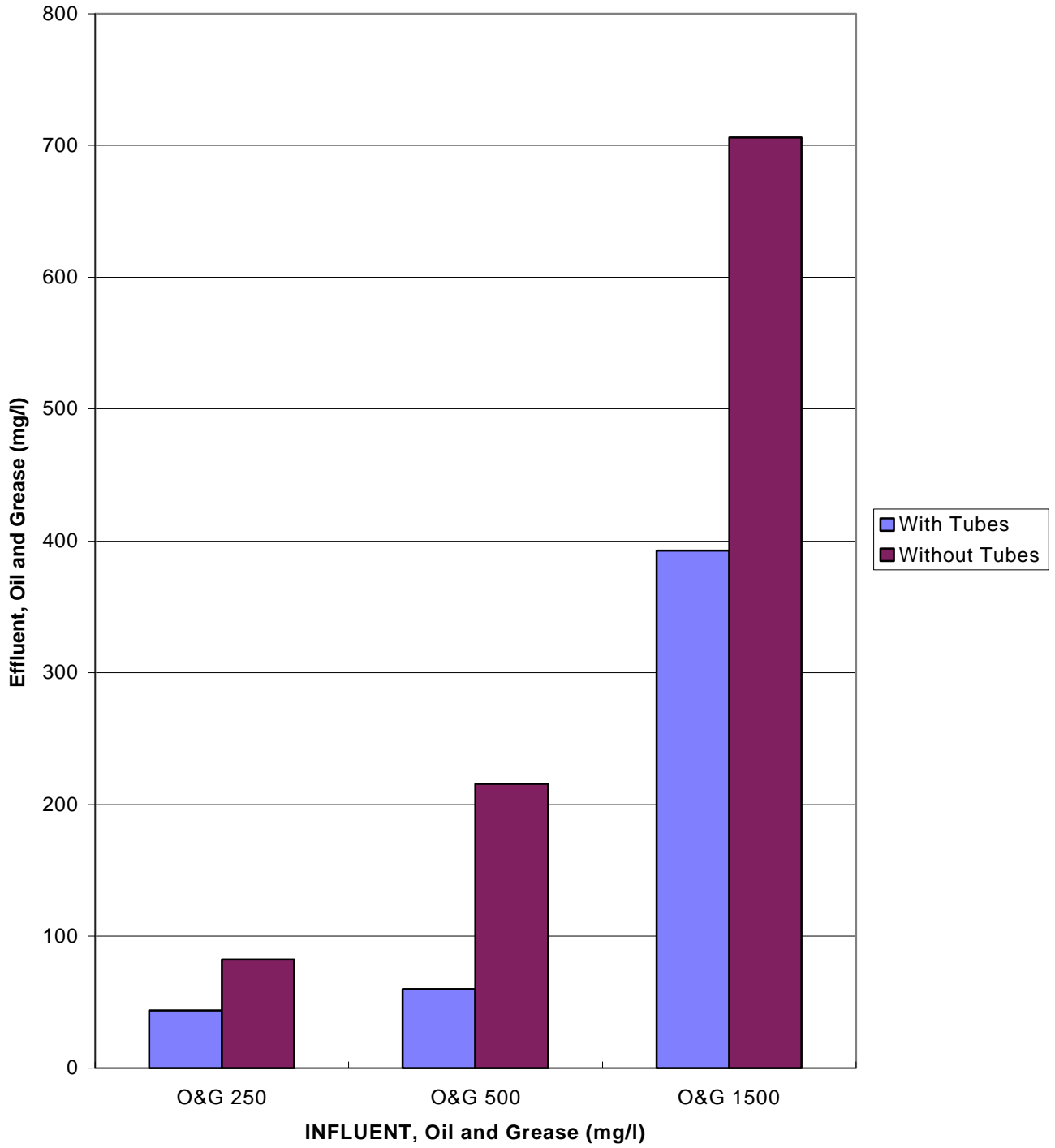


Figure B-2.2-2. OWS effluent (3 gpm), oil and grease.

**Oil / Water Separator Effluent (5 GPM)
Oil and Grease**

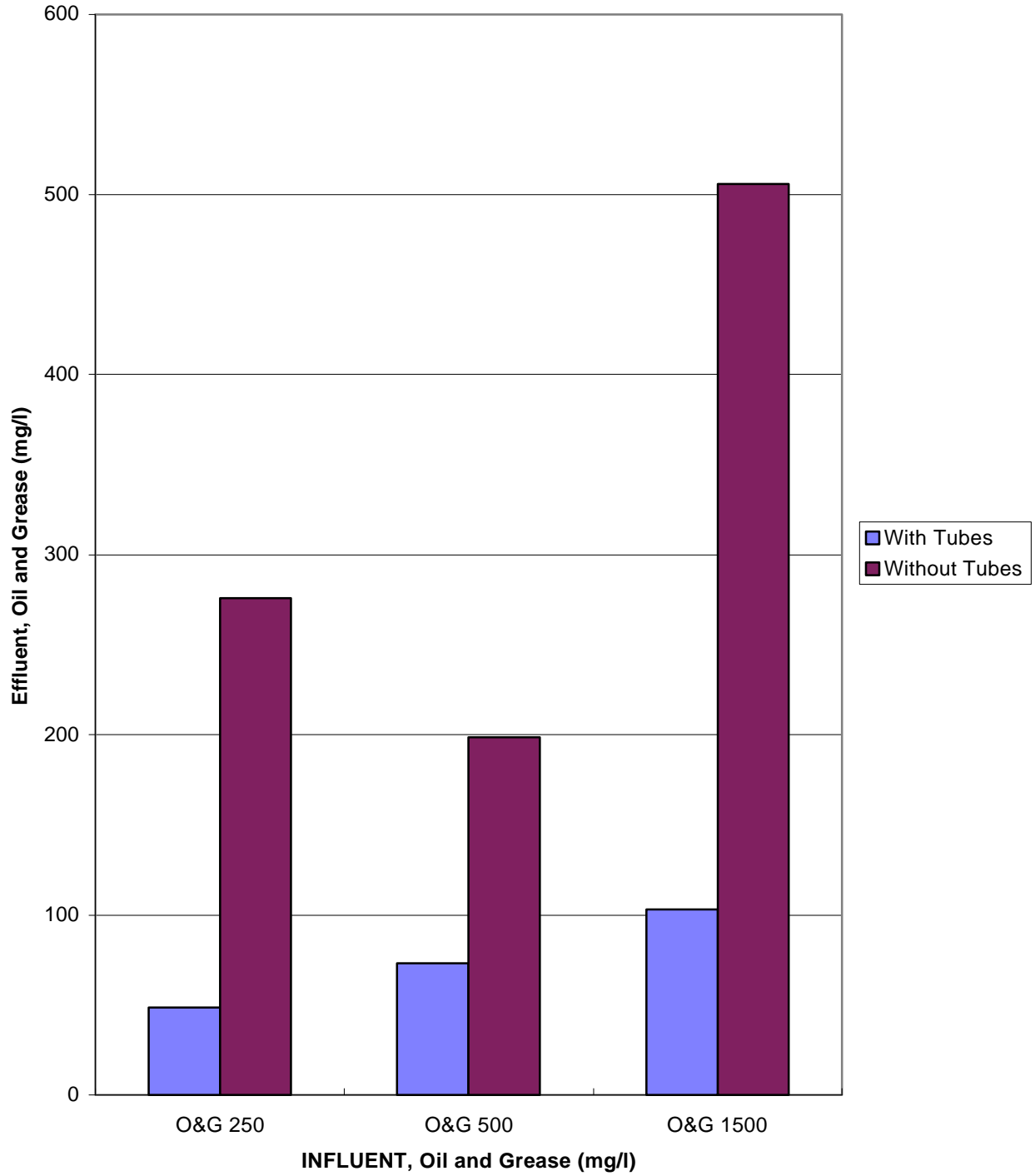


Figure B-2.2-3. OWS effluent (5 gpm), oil and grease.

**Oil / Water Separator Effluent (7 GPM)
Oil and Grease**

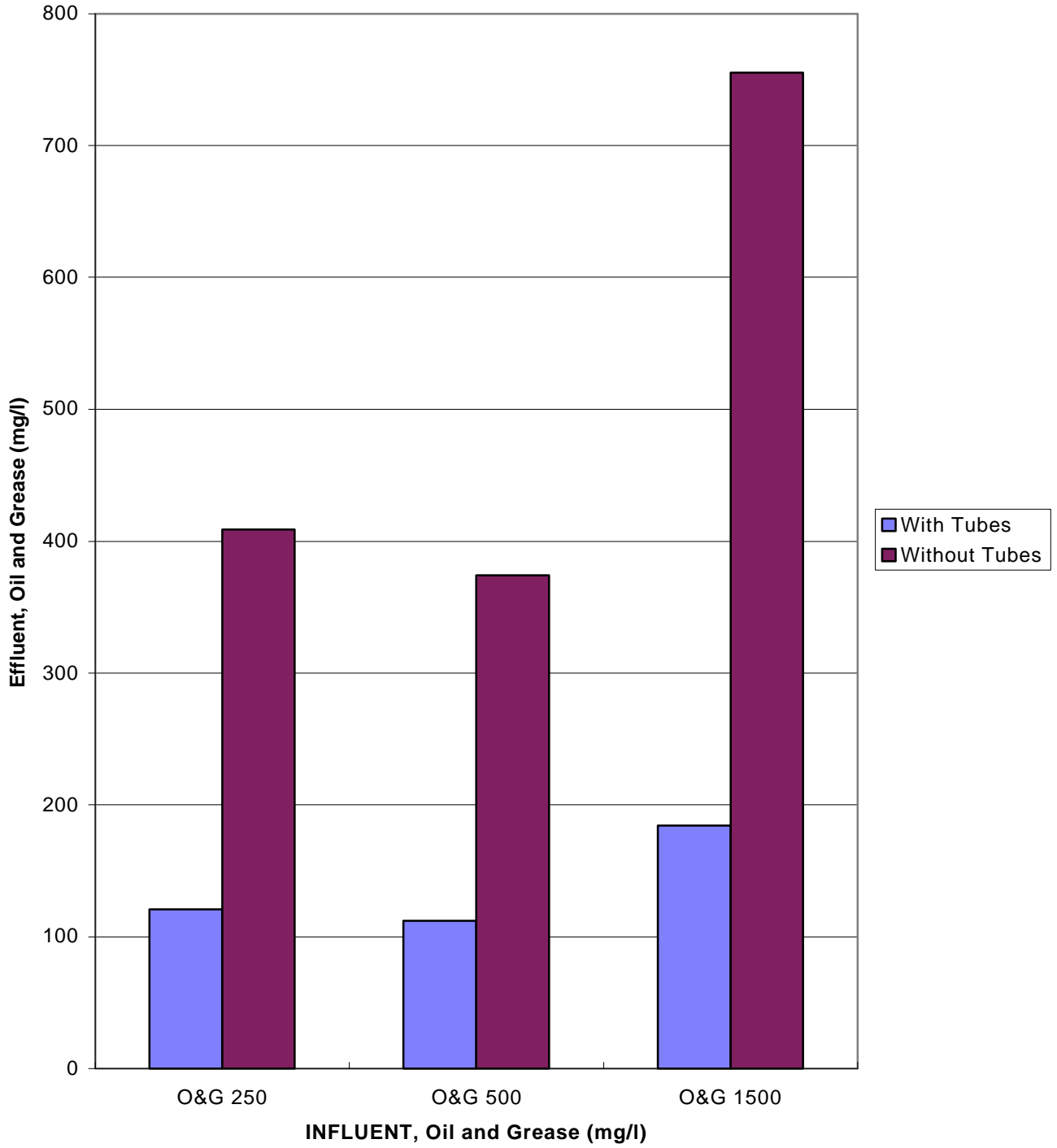


Figure B-2.2-4. OWS effluent (7 gpm), oil and grease.

**Average Oil / Water Separator Efficiency (1 GPM)
Oil and Grease**

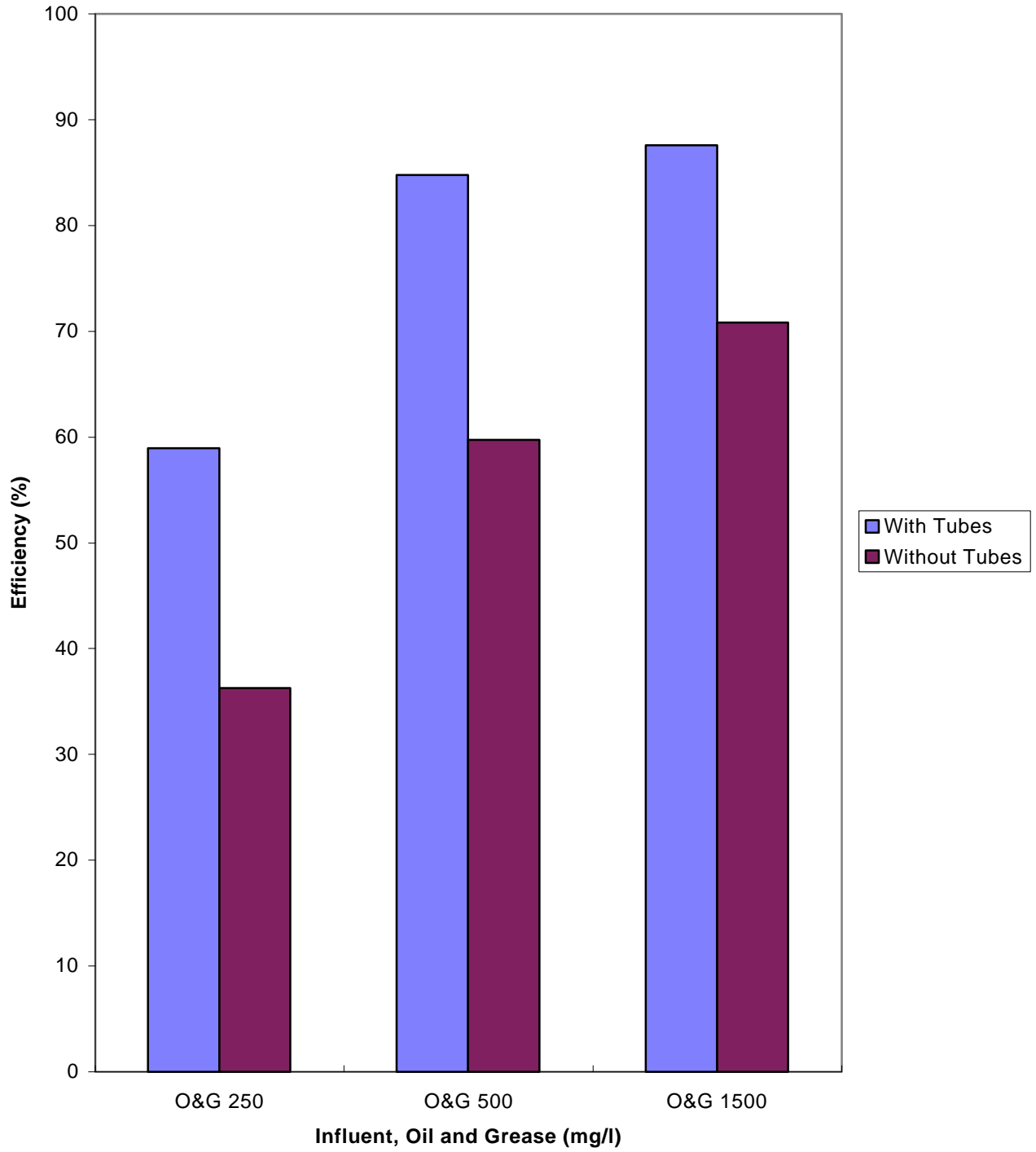


Figure B-2.2-5. Average OWS efficiency (1 gpm), oil and grease.

**Average Oil / Water Separator Efficiency (3 GPM)
Oil and Grease**

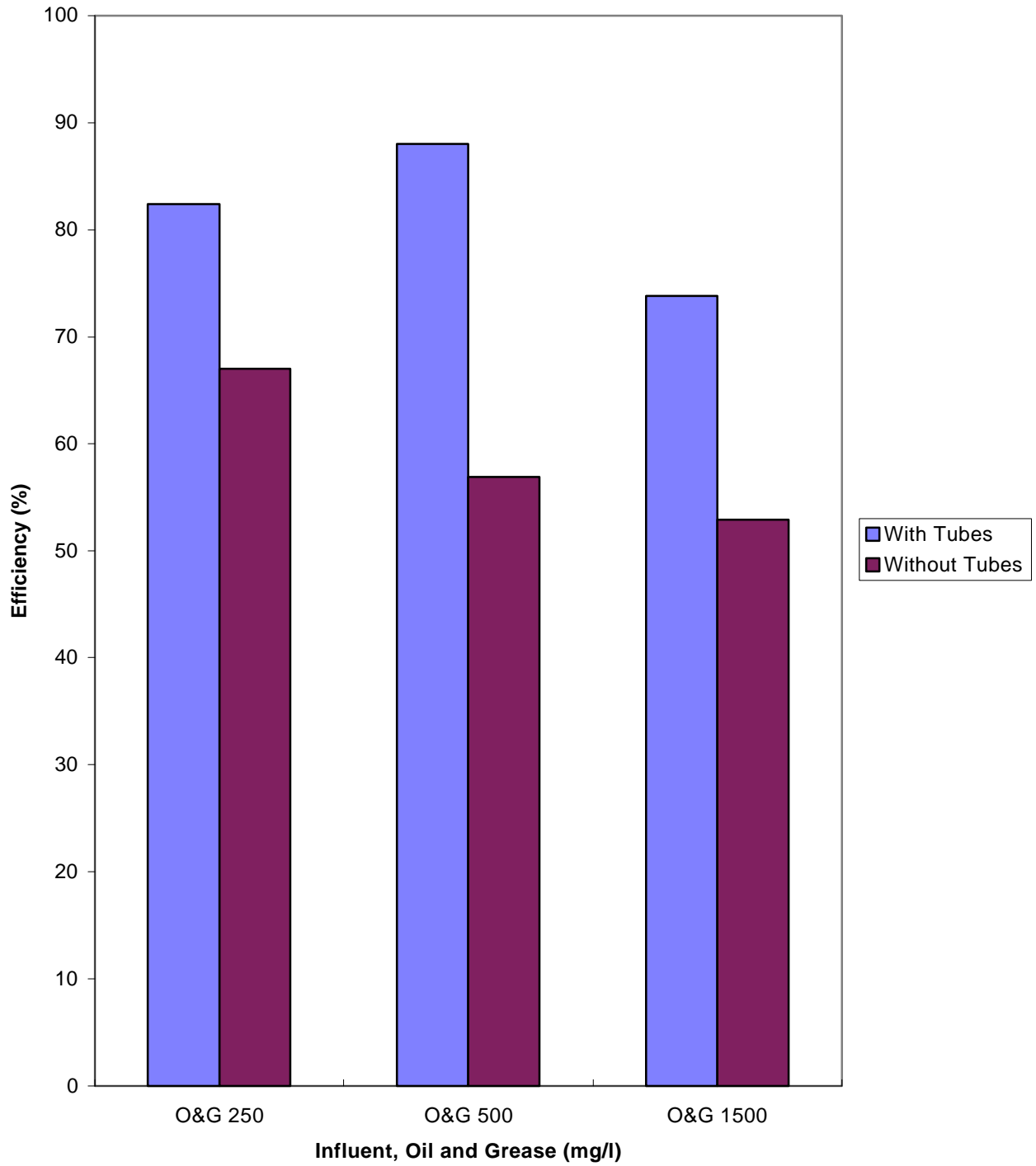


Figure B-2.2-6. Average OWS efficiency (3 gpm), oil and grease.

**Average Oil / Water Separator Efficiency (5 GPM)
Oil and Grease**

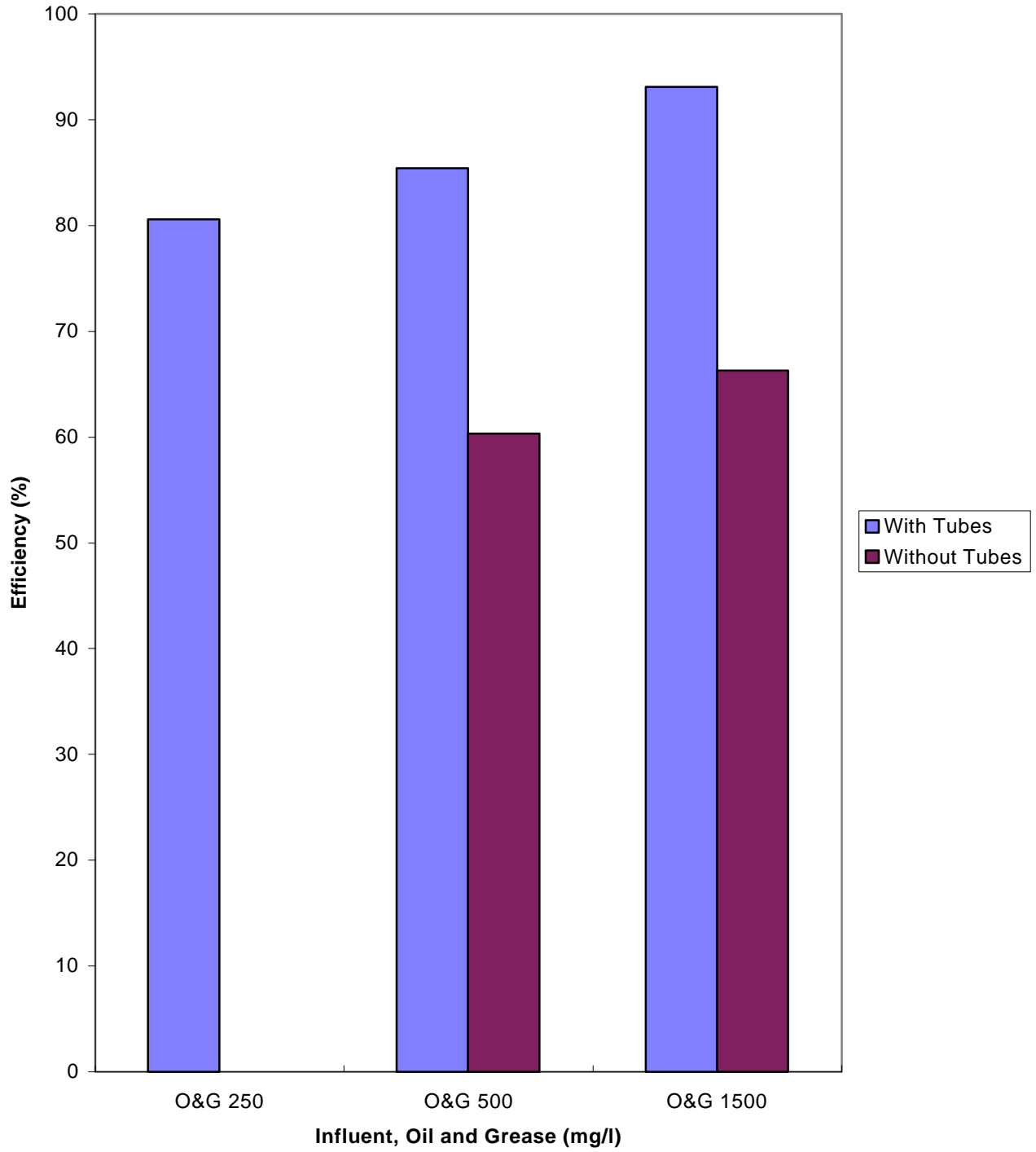


Figure B-2.2-7. Average OWS efficiency (5 gpm), oil and grease.

Average Oil / Water Separator Efficiency (7 GPM)

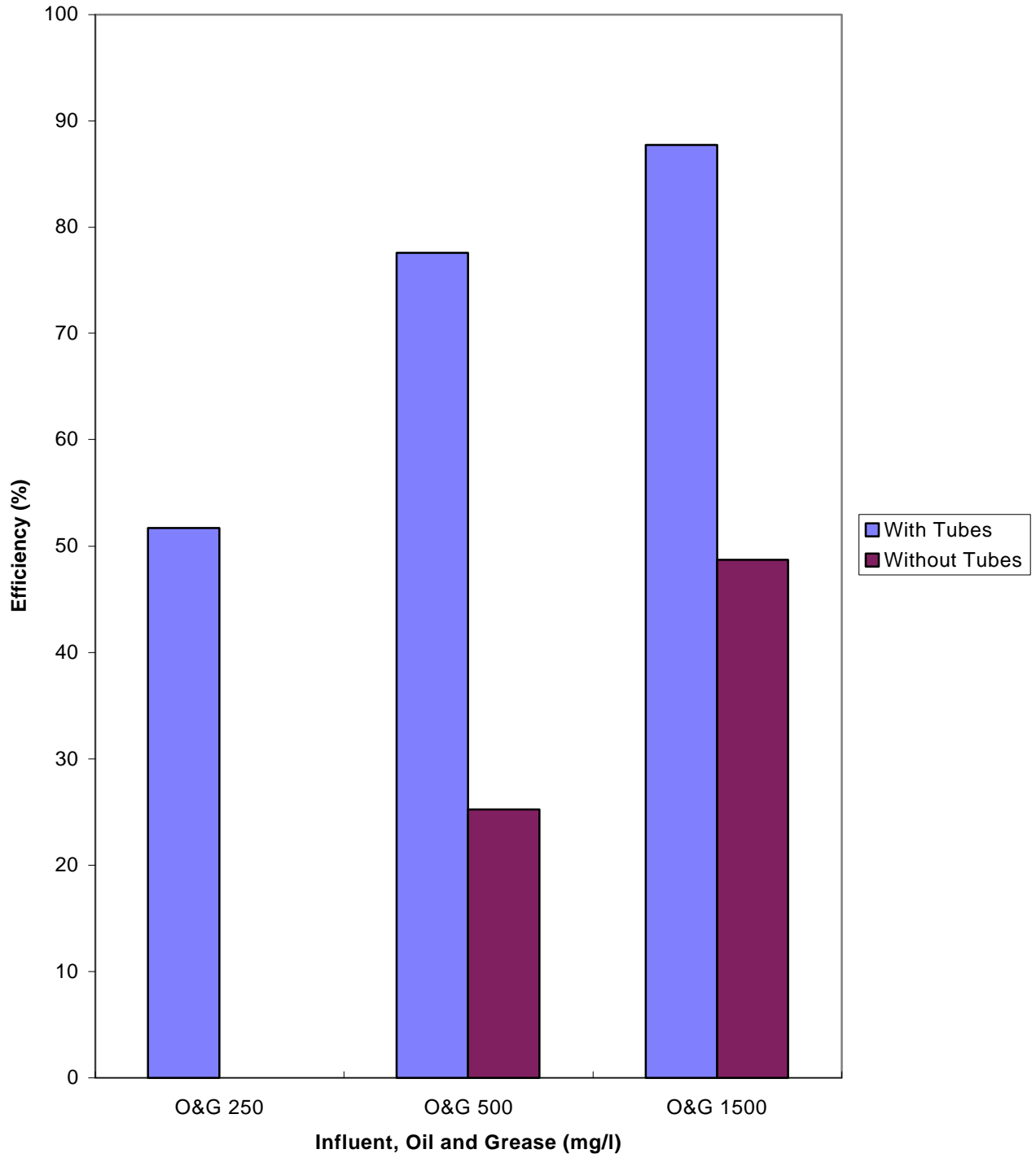


Figure B-2.2-8. Average OWS efficiency (7 gpm).

**Specific Oil / Water Separator Efficiency (1 GPM)
Oil and Grease**

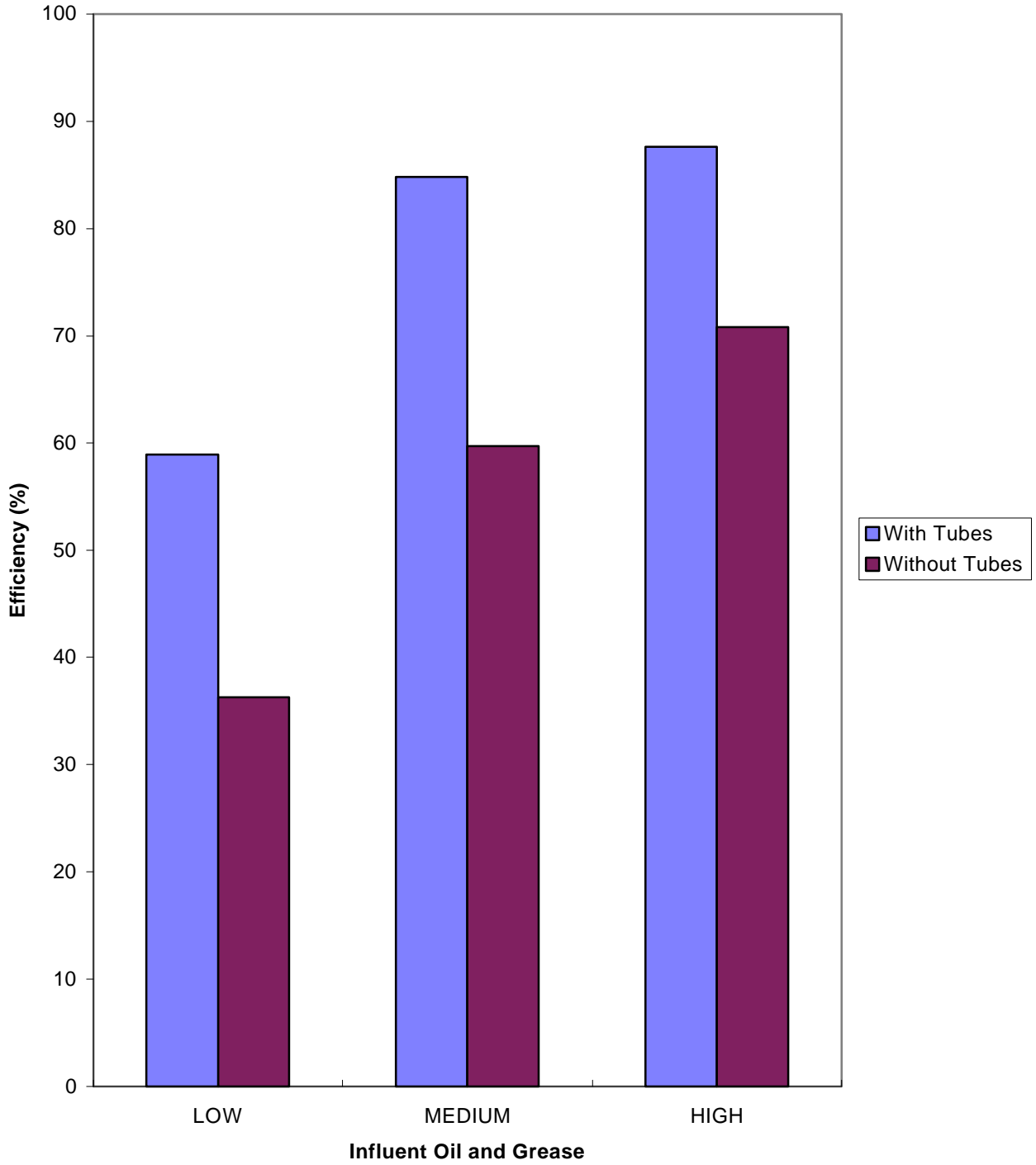


Figure B-2.2-9. Specific OWS efficiency (1 gpm), oil and grease.

**Specific Oil / Water Separator Efficiency (3 GPM)
Oil and Grease**

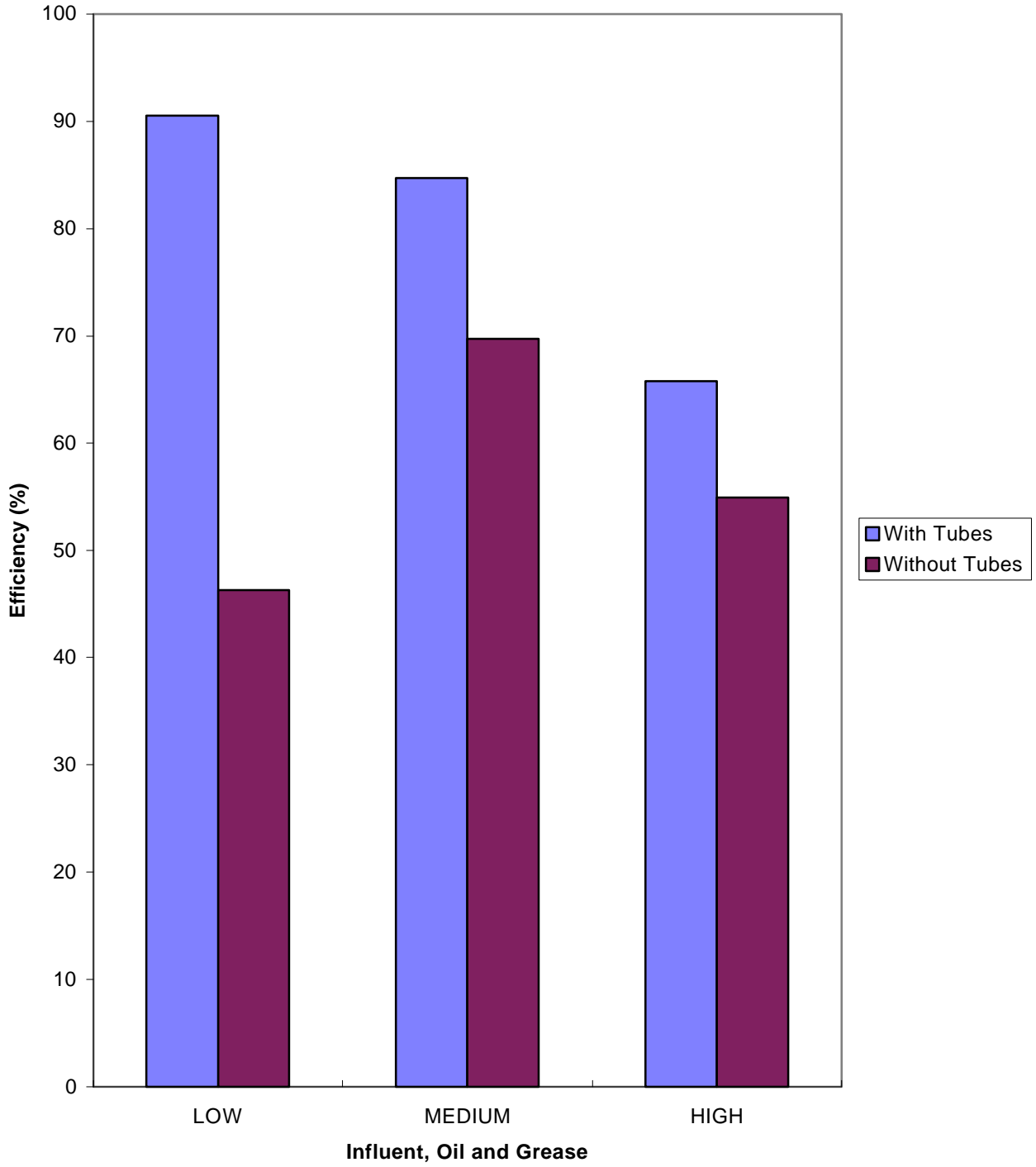


Figure B-2.2-10. Specific OWS efficiency (3 gpm), oil and grease.

**Specific Oil / Water Separator Efficiency (5 GPM)
Oil and Grease**

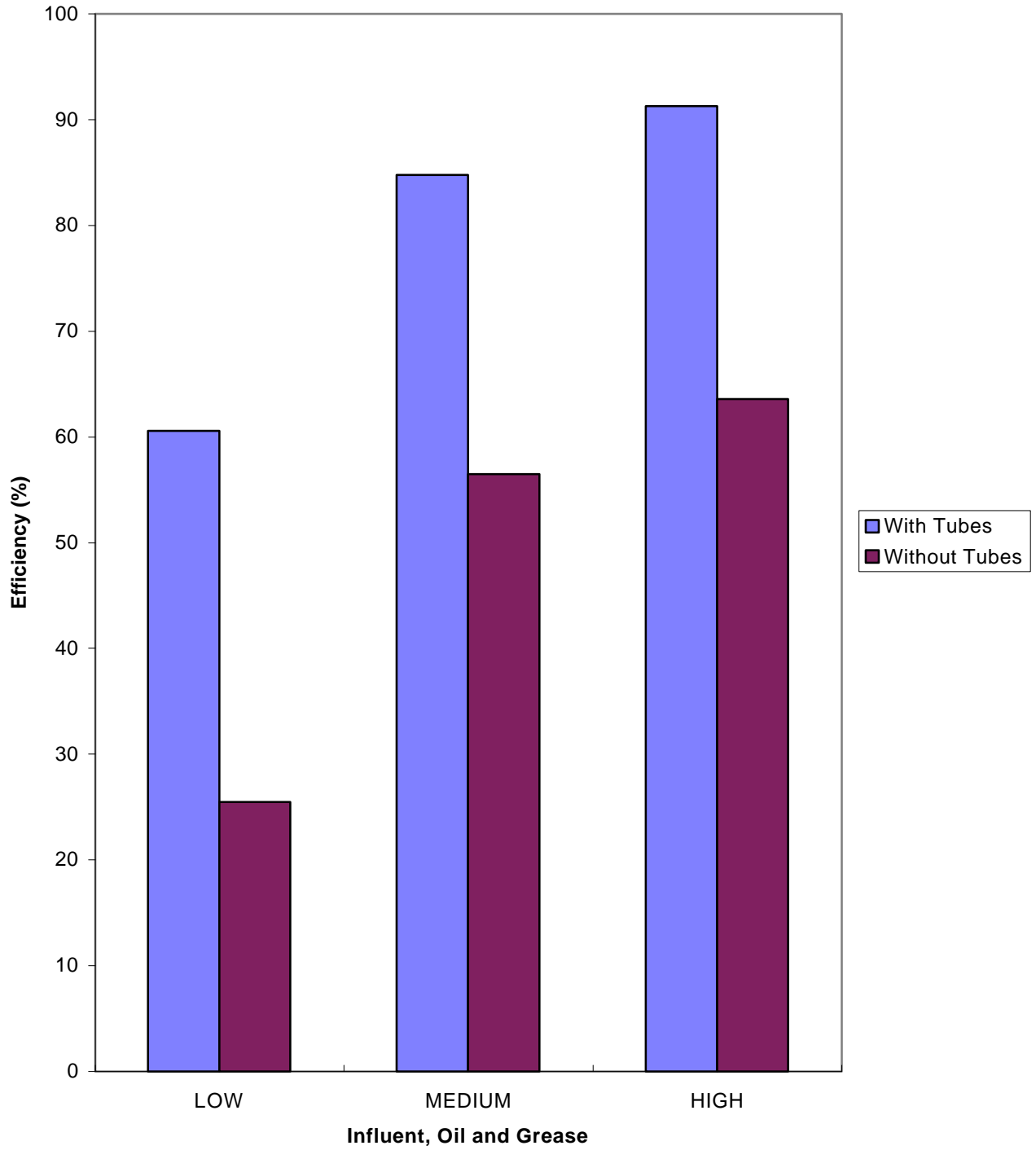


Figure B-2.2-11. Specific OWS efficiency (5 gpm), oil and grease.

**Specific Oil / Water Separator Efficiency (7 GPM)
Oil and Grease**

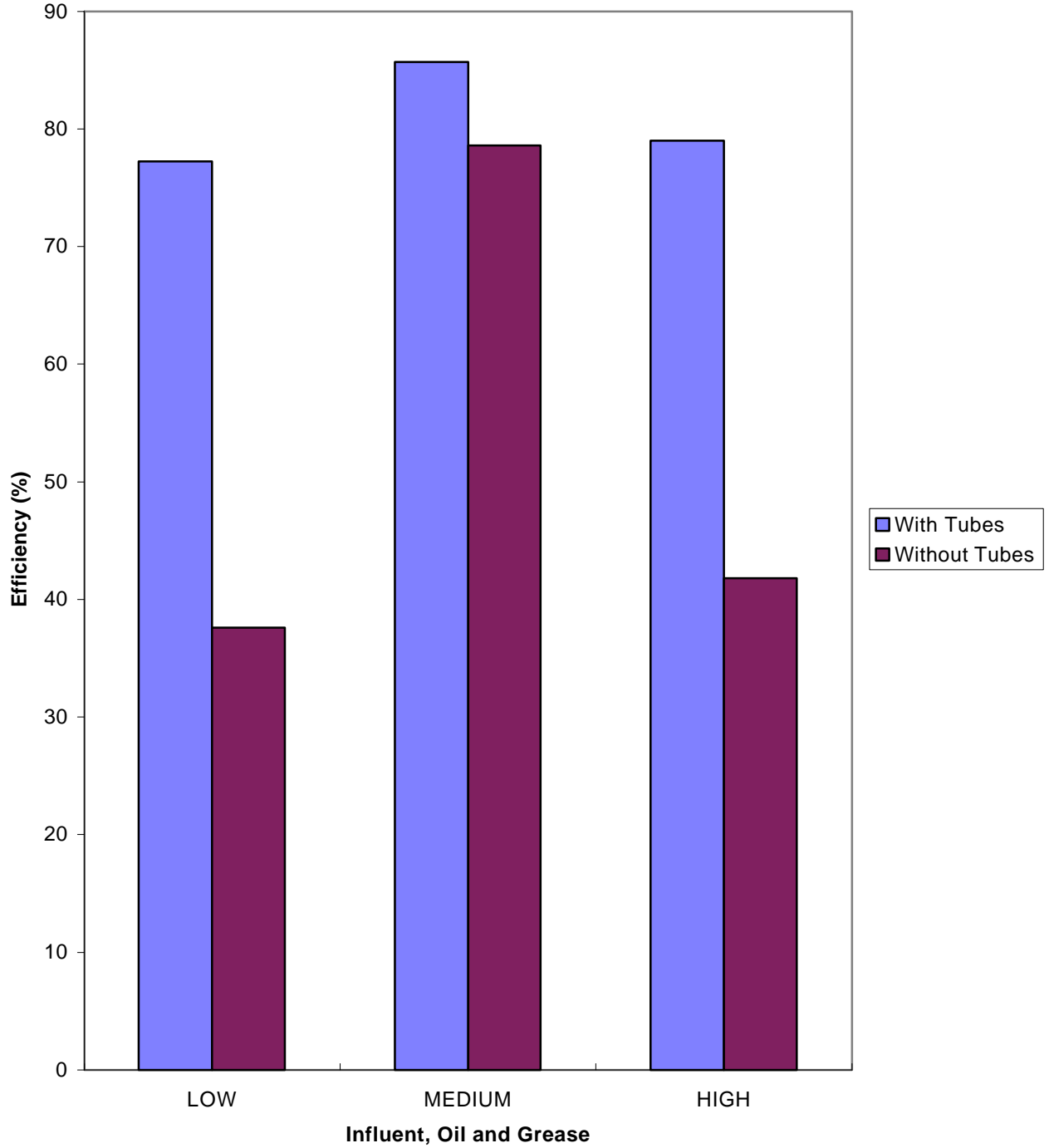


Figure B-2.2-12. Specific OWS efficiency (7 gpm), oil and grease.

TABLE B-2.3-1. pH OF EFFLUENT FOR COALESCING TUBE OWS

| 1-gpm Flowrate | Influent | | |
|------------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| Influent pH With Tubes | 6.35 | 6.29 | 6.23 |
| Influent pH No Tubes | 7.06 | 6.91 | 7.09 |
| Effluent pH With Tubes | 6.20 | 6.12 | 6.11 |
| Effluent pH No Tubes | 7.23 | 6.86 | 6.91 |

TABLE B-2.3-2. pH OF EFFLUENT FOR COALESCING TUBE OWS

| 3-gpm Flowrate | Influent | | |
|------------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| Influent pH With Tubes | 6.71 | 6.53 | 6.62 |
| Influent pH No Tubes | 6.88 | 6.54 | 6.66 |
| Effluent pH With Tubes | 6.67 | 6.60 | 6.65 |
| Effluent pH No Tubes | 6.45 | 6.84 | 6.41 |

TABLE B-2.3-3. pH OF EFFLUENT SFOR COALESCING TUBE OWS

| 5-gpm Flowrate | Influent | | |
|------------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| Influent pH With Tubes | 6.76 | 6.74 | 6.55 |
| Influent pH No Tubes | 6.62 | 6.72 | 6.55 |
| Effluent pH With Tubes | 6.78 | 6.79 | 6.67 |
| Effluent pH No Tubes | 6.84 | 6.55 | 6.64 |

TABLE B-2.3-4. pH OF EFFLUENT FOR COALESCING TUBE OWS

| 7-gpm Flowrate | Influent | | |
|------------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| Influent pH With Tubes | 6.70 | 6.99 | 7.09 |
| Influent pH No Tubes | 5.73 | 5.81 | 6.17 |
| Effluent pH With Tubes | 6.99 | 6.95 | 7.09 |
| Effluent pH No Tubes | 5.81 | 5.82 | 5.94 |

TABLE B-2.4-1. TEMPERATURE OF WASTEWATER FOR
COALESCING TUBE OWS

| 1-gpm Flowrate | Influent | | |
|---------------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| Temperature °F With tubes | 60.5 | 44 | 47 |
| Temperature °F No Tubes | 44.7 | 45.1 | 45.2 |

TABLE B-2.4-2. TEMPERATURE OF WASTEWATER FOR
COALESCING TUBE OWS

| 3-gpm Flowrate | Influent | | |
|---------------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| Temperature °F With tubes | 51.4 | 44.8 | 43.5 |
| Temperature °F No Tubes | 47.6 | 48.3 | 64.5 |

TABLE B-2.4-3. TEMPERATURE OF WASTEWATER FOR
COALESCING TUBE OWS

| 5-gpm Flowrate | Influent | | |
|---------------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| Temperature °F With tubes | 49.6 | 45.6 | 43.9 |
| Temperature °F No Tubes | 45.9 | 44.5 | 53.2 |

TABLE B-2.4-4. TEMPERATURE OF WASTEWATER FOR
COALESCING TUBE OWS

| 7-gpm Flowrate | Influent | | |
|---------------------------|-----------------|------------------|-------------------|
| | TPH 250/TSS 500 | TPH 500/TSS 2000 | TPH 1500/TSS 6500 |
| Temperature °F With tubes | 43.4 | 53.0 | 48.0 |
| Temperature °F No Tubes | 47 | 49 | 57 |

APPENDIX C. TEST MATRIX AND WASTE WATER CONCENTRATIONS

OWS Test Condition No. 1 (with Coalescing Tubes)

| 3 gpm | Low | Medium | High |
|------------|-----|--------|------|
| TPH (mg/L) | 250 | 500 | 1500 |
| TSS (mg/L) | 500 | 2000 | 6500 |

OWS Test Condition No. 2 (with Coalescing Tubes)

| 5 gpm | Low | Medium | High |
|------------|-----|--------|------|
| TPH (mg/L) | 250 | 500 | 1500 |
| TSS (mg/L) | 500 | 2000 | 6500 |

OWS Test Condition No. 3 (with Coalescing Tubes)

| 7 gpm | Low | Medium | High |
|------------|-----|--------|------|
| TPH (mg/L) | 250 | 500 | 1500 |
| TSS (mg/L) | 500 | 2000 | 6500 |

OWS Test Condition No. 4 (without Coalescing Tubes)

| 1 gpm | Low | Medium | High |
|------------|-----|--------|------|
| TPH (mg/L) | 250 | 500 | 1500 |
| TSS (mg/L) | 500 | 2000 | 6500 |

OWS Test Condition No. 5 (without Coalescing Tubes)

| 3 gpm | Low | Medium | High |
|------------|-----|--------|------|
| TPH (mg/L) | 250 | 500 | 1500 |
| TSS (mg/L) | 500 | 2000 | 6500 |

OWS Test Condition No. 6 (without Coalescing Tubes)

| 5 gpm | Low | Medium | High |
|------------|-----|--------|------|
| TPH (mg/L) | 250 | 500 | 1500 |
| TSS (mg/L) | 500 | 2000 | 6500 |

OWS Test Condition No. 7 (with Coalescing Tubes)

| 1 gpm | Low | Medium | High |
|------------|-----|--------|------|
| TPH (mg/L) | 250 | 500 | 1500 |
| TSS (mg/L) | 500 | 2000 | 6500 |

OWS Test Condition No. 8 (without Coalescing Tubes)

| 7 gpm | Low | Medium | High |
|------------|-----|--------|------|
| TPH (mg/L) | 250 | 500 | 1500 |
| TSS (mg/L) | 500 | 2000 | 6500 |

APPENDIX D. SPECIFIC GRAVITY AND VISCOSITY OF OILS

| Oil Type | Specific Gravity at 20 °C | Viscosity at 100 °C | Viscosity at 40 °C |
|--------------------------|------------------------------|------------------------|-----------------------|
| Kerosene | 0.8062 | - | 1.37 |
| Dextron III | 0.8651 | 7.5 | 32.96 |
| 5Ww-30 | 0.8677 | 10.1 | 60.29 |
| Power Steering Fluid | 0.8697 | 6.4 | 42.67 |
| 10W | 0.8772 | 7.1 | 45.41 |
| 10W-30 | 0.8781 | 14.4 | 64.07 |
| 15W-40 | 0.8811 | 9.9 | - |
| 30W | 0.8857 | 10.3 | - |
| 80W-90 | 0.8975 | 14.7 | - |
| Turbine Oil | 0.9891 | 4.9 | 24.36 |
| Brake Fluid | 1.0383 | - | 6.96 |
| Antifreeze/Water (50/50) | 1.0661 | - | - |
| Antifreeze | 1.1233 | - | - |

APPENDIX E. REFERENCES

1. ASHRAE Refrigeration Handbook, 1991.
2. ASHRAE Fundamentals, 1993.
3. CRC Handbook of Chemistry and Physics.
4. EPA Method 1664, N-Hexane Extractable Material and Silica Gel Treated N-Hexane Extractable Material by Extraction and Gravimetry (Oil and Grease and Total Petroleum Hydrocarbons), January 1995.

APPENDIX F. ABBREVIATIONS

| | |
|--------|-----------------------------------|
| AEC | = U.S. Army Environmental Center |
| APG | = Aberdeen Proving Ground |
| DOD | = Department of Defense |
| EPA | = Environmental Protection Agency |
| MACOMS | = U.S. Army major commands |
| OWS | = oil/water separator |
| TPH | = total petroleum hydrocarbon |
| TSS | = total suspended solids |
| VCT | = vertical coalescing tube |
| USACE | = U.S. Army Corps of Engineers |

APPENDIX G. DISTRIBUTION LIST

TECOM Project No. 9-CO-160-000-374

| Addressee | No. of Copies |
|---|------------------|
| Commander U.S. Army Test and Evaluation Command ATTN: AMSTE-TM-O (Mr. Fisher) Aberdeen Proving Ground, MD 21005-5055 | 1 |
| Commander U.S. Army Environmental Center ATTN: SFIM-AEC-ETT (Mr. Dennis Teefy) Aberdeen Proving Ground, MD 21010-5401 | 40 |
| Commander U.S. Army Construction Engineering Research Laboratory ATTN: CECER-UL-T (Mr. Gary L. Gerdes) PO Box 9005 Champaign, IL 61826 | 1 |
| Department of the Army Assistant Chief of Staff, Installation Management, Utilities Branch ATTN: DAIM-FDF-U (Mr. Hank Gignilliant) 7701 Telegraph Road, Building 2594 Alexandria, VA 22315-3800 | 1 |
| United States Environmental Protection Agency ATTN: Ethan McMahon (6202J) Jeffrey Levy (6205J) 401 M Street, SW Washington, DC 20460 | 1 1 |
| Director U.S. Army Research Laboratory ATTN: AMSRL-OP-AP-L, Building 305 Aberdeen Proving Ground, MD 21005-5066 | 1 |

| <u>Addressee</u> | <u>No. of Copies</u> |
|--|--------------------------|
| Commander U.S. Army Aberdeen Test Center ATTN: STEAC-SF-C (Mr. Klara) | 3 |
| STEAC-TC-M (Mr. Hudson) | 15 |
| STEAC-SC-A | 1 |
| Aberdeen Proving Ground, MD 21005-5059 | |
| Defense Technical Information Center 8725 John J. Kingman Road, Suite 0944 Fort Belvoir, VA 22060-6218 | 2 |

Secondary distribution is controlled by Commander, U.S. Army Environmental Center,
ATTN: SFIM-AEC-ETT.