QUARTERLY PROGRESS REPORT #1

ON DEVELOPMENT OF

THE OIL-WATER MONITOR

by

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for the

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1. INTRODUCTION

The Oil-Water Monitor is a device which has been invented by Dr. Claude Swanson of Applied Physics Technology (APT), which is capable of accurately measuring the water content in crude oil in a flowing pipe. The device is based on absorption measurements of microwave energy which passes through the crude oil as it flows, and is applicable to cases in which the water content is very high or in cases where the water distribution is inhomogeneous, i.e. when there are large globules of water present in the flow. This is often the case when oil tankers are loaded or unloaded or when oil is transferred from pipelines or ships to refineries. The device is also useful at transfer points for oils with high water content, such as oil from Tertiary recovery wells in the Southwestern U.S.

The technique is based on making many microwave absorption measurements at different frequencies, and processing the measurements using an Inverse Laplace transform. The techniques underlying the device have been patented, and a simple lab demonstration has been conducted to verify the concepts.

The development of this device is being supported in the present DOE Energy-Related Inventions Program because, without the detection and accurate measurement water content in oil shipments, there is a significant economic loss to the oil purchaser or the oil importer, in this case the United States. Interest in the APT Oil-Water Monitor has been expressed by major U.S. Oil Companies and shippers, who have stated that the capability offered by the Oil-Water Monitor is needed by the industry.

In the present report, we wish to describe the activities and progress accomplished during the first three month period of support under the Department of Energy Grant DE-FG01-89CE15444. The purpose of the work conducted under this grant, under the Energy Related Inventions Program (ERIP) is to continue in the development of the Oil-Water Monitor, and in particular to produce a bench model prototype which makes computer controlled measurements of the water content in the crude oil.

Under the present grant will be developed the computer software, computer algorithms, and antenna design which will be essential to a later full-scale prototype. The most important goal of the work under the present grant is the demonstration of a bench model prototype which has most of the characteristics of the eventual full-scale design.

The bench model prototype will also provide a demonstration of the performance and accuracy of the device, and will be valuable in convincing investors, licensing partners or venture capitalists in providing the investment required for construction of the full-scale prototype. In this regard, APT has made progress in seeking partners to assist in the further development of the device. This will be discussed in a later section.

II. TECHNICAL PROGRESS - FIRST REPORTING PERIOD

In this first quarter of activity, there were several accomplishments made. The following summarises these activities and accomplishments:

(1) A detailed theoretical analysis was undertaken to review the assumptions made in the calculation of microwave absorption versus frequency, and to refine these calculations to provide a theoretical base for the processing software to be developed. In particular the effects of edge diffraction in the propagation of microwaves around water globules in crude were considered. The effects of particulates and inorganic matter as a contaminant were also analyzed to assess their effect as a source of error in the measurements. The theoretical effort also considered the effect of the presence of air in the fluid, and the effect of frequency drift on errors in the measurement accuracy.

(2) An extended search was made to locate and borrow government surplus microwave equipment, or government owned microwave test equipment not presently being used, which were of the appropriate type to be useful in the oil-water tests. However, after discussions with personnel at the Department of Energy, the Naval Research Laboratory, the U.S. Geological Survey, and others it was concluded that the required equipment was unavailable through this route. Therefore, A.P.T. made the decision to rent the

necessary test equipment at its own expense, and not to charge these expenses to the grant. This was consistent with the provisions of the grant, and APT budgetary planning, in which A.P.T. agreed to provide the necessary test equipment if it could not be procured through government surplus sources.

(3) The next step in the equipment acquisition effort was identification and acquisition of the required test equipment. After extensive discussions with several vendors, the Willtron 560A Network Analyzer, the Willtron 6669B Microwave Signal Generator, the Willtron 560-7K50 Detector, two microwave feed horns, and various support equipment were identified as an appropriate test set-up for the measurements to be made. It was decided that flexible IW Cable microwave coax cable would be used throughout the system, with K connectors as standard.

(4) An appropriate Analog to Digital Converter board (A/D) was identified which inserts in an IBM compatible computer, and can be used for control and data acquisition during the experiment. The card selected is the DASH-16, manufactured by Metrabyte Corporation, which has a maximum throughput of 35 KB/sec. The card was acquired and successfully tested in A.P.T.'s 386 computer. The card will be used both for sending information to the Willtron Network Analyzer, and for receiving absorption data from the Network Analyzer. It also controls the chirping of the microwave signal, and calibrates and converts the received data to compute the water content in the crude oil.

(5) It was decided that the experiment would be under the control of the A.P.T. 386 Hauppauge Computer, and that GPIB would be the control language used during the experiments. The computer capability was upgraded to 33 MHz, and a very large 330 MByte hard disk was installed to facilitate the acquisition of large amounts of data. The purchase of these items was made on A.P.T. overhead expense and was not billed directly to the grant, even thogh the purpose of these items is primarily to support the oil-water monitor development.

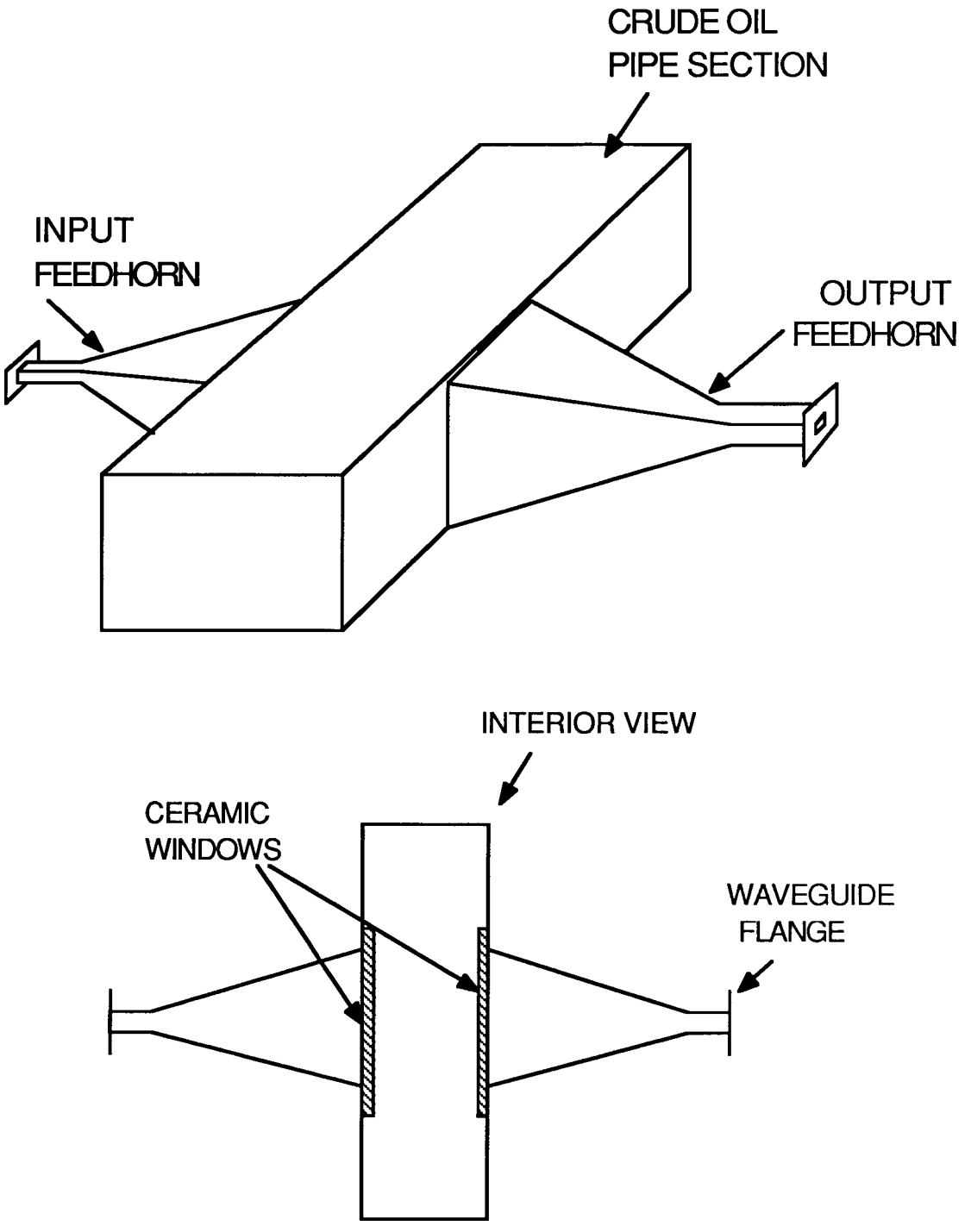
CRUDE OIL
PIPE SECTION
INPUT
FEEDHORN
OUTPUT
FEEDHORN
INTERIOR VIEW
CERAMIC
WINDOWS
WAVEGUIDE
FLANGE

FIGURE 1

(6) The computer package ASYST was acquired to support GPIB programming of the Willtron Network Analyzer during the experiments. Both the A/D Card and the ASYST package were purchased with A.P.T. overhead funds, and no DOE grant funds were used for these purchases.

(7) A microwave antenna system was designed which would accomodate the introduction of microwave energy into the test section, in which crude oil was present, and consisting of a second feed horn which would measure the transmission losses across the crude oil pipe. A diagram of the antenna design is enclosed as Figure 1. Construction was begun on the antenna system.

(8) A five gallon drum of crude oil was obtained from British Petroleum Refinery, Marcus Hook, PA, for use in the upcoming experiments,

(9) An effort was begun to learn the ASYST programming language and the GPIB programming language. These languages are required in order to design the software for control of the experiment and analysis of the data.

III. COMMERCIAL PROGRESS

Although commercialisation of the Oil-Water is not a requirement of the present grant work, nevertheles it is understood that progress toward the commercialization of these devices is one of the purposes and end goals of the ERIP program. Therefore, we are including here the efforts conducted during this period with regard to licensing and obtaining commercial or Venture invstrment in this device.

(1) Mr. Don Witschieben, a former Senior Vice President of Mobil Oil Corporation is working with A.P.T. in seeking funding support and laboratory from Mobil to assist in the development of the full scale prototype. Mr. Witschieben has carried out discussions with the present and former Presidents of Mobil, and has stated that, depending on the success of the present bench top prototype experiment, Mobil may be very interested in supporting commercial development of the device.

(2) An agreement was signed with Brooklawn Associates, Inc. to develop the legal licensing documents and to identify a list of potential licensees, in order to secure a licensing agreement agreement for the Oil-Water Monitor patents.

(3) Discussions were carried out and a presentation was made to American Research and Development (ARD), one of the largest and most prestigious venture capital groups, located in Boston, Massachusetts. Discussions are ongoing with them.

(4) A presentation was made to the U.S. Navy, PMS-390, which is in charge of ship and submarine maintenance issues, and has indicated a concern over the effect of small amounts of water contimantion in several ship board systems. The presence of water in these systems causes corrosion and rapid deterioration in valves and other critical systems. It poses a maintenance problem and a safety hazard in hydraulic high pressure lines which are used on submarines for ballast control. The detection of water is also important in refrigerations systems and nuclear reactors. Discussions are ongoing with this group about the potential application of the oil-water monitor to meet these requirements.

IV. CONCLUSIONS

The development of the bench model prototype oil-water under the present grant is proceeding on-schedule and on-budget. Budgetary information is enclosed in DOE Form 272, "Federal Cash Transactions Report", and Form F538-(5-86), attached as Appendix I. Development effort was begun in all areas necessary to develop the prototype oil-water monitor. Efforts included: (1) Further theoretical development of the mathematical model of the measurement process; (2) An experimental design was developed; (3) Appropriate instruments and components were identified, some were acquired and acquisition procedures were initiated for others; (4) Acquisition of software was initiated, and programming efforts began, both for experimental control and data analysis; (5) The microwave antenna

system was designed and fabrication began; (6)Discussions were held with several potential commercial partners regarding commercialization of the oil-water monitor.

Budget removed. dz