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"DETERMINING OPERATIONAL POLICIES FOR OIL FLOW AND TANKER LOADING THROUGH SIMULATION"

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In this paper the use of simulation in addressing the specific needs of one oil company's tanker scheduling problem is examined. The situation is actually more involved than simply tanker scheduling. The flow of oil from the wells to the storage facility must also be considered. This flow is constrained by governmental regulations and profit considerations. A network-discrete event-continuous simulation model, written in SLAM, was developed to address certain issues of interest to the oil company. These were issues such as a desirable mean time between tanker arrivals and the adequacy of the current storage facility. The latter was also of interest to the government involved, since there were usually tankers waiting to be loaded. The results show that tanker arrival schedule can be developed and that the current storage facility is adequate to meet this company's needs.

I. INTRODUCTION

One of the problems facing a number of petroleum producing companies is the lack of adequate storage for the crude oil produced. In some cases, this may be due to uncertainty and irregularity of export tanker arrivals to load from the present storage facilities. In the case examined here, limited storage facilities have also resulted in numerous shut downs of producing wells. Of course, when some wells are not producing, the total daily production drops. Since production cuts are not economical to a company's operations, it becomes necessary to develop a schedule of export tanker arrivals and loading operations. When the export tankers arrive on schedule, to load from the storage facilites, there will be enough space for the oil produced from the wells to be stored without shutting them down.

This paper discusses the initial results of model development toward addressing these problems.There are actually two decisions which must be made, and they are very much interdependent. The obvious requirement is the development of an export tanker arrival schedule. Such a schedule would specify desired tanker arrival dates. There are many factors which would affect the true arrival date, so this is indeed a random variable.

The second decision process involves the flow of oil from the producing wells to the storage facility. This is dependent on export tanker arrivals. A long time period between tanker arrivals could result in well shut-downs due to full storage facilities. Thus, the flow of oil from the wells should be coordinated with the tanker arrival schedule to yield best results. Constraints on oil flow actually assist in making the problem manageable.

These decisions are combined to arrive at a conclusion regarding the adequacy of current storage facilities. A debate is currently underway concerning the need for additional storage capacity. Additional capacity may not be necessary if oil flow and tanker arrivals can be properly balanced.

The situation depicted here is specific to a particular oil company and oil exporting country, neither of which will be named in this paper. However, it is evident that similar situations exist elsewhere (not restricted to oil companies).

II. Overview of Operations

In this section the particular operations under consideration are described. This includes a description of the operational system from which the simulation model was built, plus system constraints imposed either by the company or the government.

Figure 1 presents a graph of the system. This has been simplified somewhat for clarity of explanation. Production begins at the producing wells. In most instances, the fluid at this point consists of a mixture of oil, gas, and water. The production rate is controlled by an adjustable choke. The fluid flows from the numerous producing wells to a "tank battery." The tank battery is used to separate the water and gas from the oil. While no oil storage is possible at the well site, a small inventory exists at the tank battery to ensure a continuously operating system. This small amount of storage, however, is not considered as possible storage.

Upon leaving the tank battery the oil travels to the storage facility. At the current time only one such facility is being used. One of the ultimate objectives of this project is to determine if the existing facility provides adequate storage capacity. At this point the oil is held in storage until an export tanker arrives to load. Of course the arrival of a tanker represents oil leaving the system.

The major entity in this system is the storage facility. Due to the nature of the facility, it has both an upper and a lower limit on the quantity of oil allowed in storage. The flow of oil from the wells dictates the rate at which the oil level increases, and the arrival of export tankers dictates the rate at which the oil level decreases. (Actually, the rate at which oil is pumped to the export tanker is constant, but is dependent on the presence of the tanker.) Therefore, the system revolves around the storage facility by tracking oil flow from the wells (via the tank battery) and tanker arrivals. Although well shut-downs are not desirable, specific procedures must be established in the event of a full storage facility. These are developed for the simulation.

Finally, both the company and the government have a keen interest in the rate of oil flowing from the wells. Certainly every barrel of oil means income to both parties, and is therefore desirable. Below a certain level there is no profit for the company. However, the government wishes to conserve it's oil reserves, so an upper limit on the flow is established. Fortunately, these limits serve not to complicate the problem but to make it easier.

III. SYSTEM PARAMETERS

There are several system parameters which must be specified for problem analysis. These parameters concern tanker arrivals and oil flow through the oil network. They are constrained by operational considerations and common sense.

First, consider the export tanker arrival rate. In scheduling tanker arrivals it is desirable to schedule according to the time between tanker arrivals. This is, of course, a random variable. Many factors may affect the time it takes for a tanker to travel from one port to the next. The analysis presented here does not consider these various factors specifically, but is concerned only with the total tanker interarrival rate.

Issues of importance in this regard are the interarrival time distribution used and the mean and variance of this distribution. Past data is an excellent source of such information. However, the mean interarrival time used is a determinant of the tanker schedule. Therefore, the choice of a mean (and a corresponding variance) is used in the analysis to dictate a tanker arrival schedule. Common sense restricts the mean interarrival time to a particular range of values. This range is based on the possible oil flow rates, which are discussed below.

The description of oil flow parameters will proceed from the export tanker loading operation, backward to the producing wells. The rate at which export tankers are loaded is 45,875 barrels per day. This is a fixed value for this analysis, and represents the rate of flow of oil leaving the storage facility.

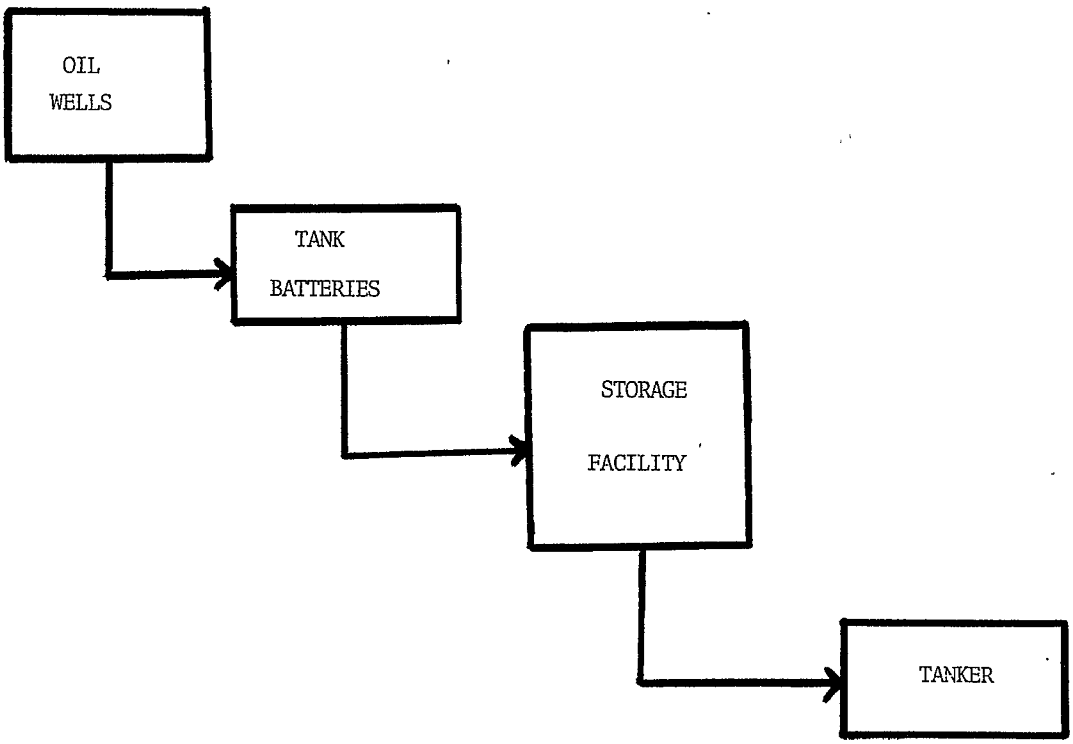

FIGURE 1. SYSTEM OPERATIONS

The oil flow into the storage facility is the same as the flow leaving the tank battery. Of course, this is dependent on the flow from the wells. Total oil flow from the wells is an important factor both for the company and the government. Here, oil flow means equivalent oil quantities, not including the oil and gas present. The company has a particular break-even production rate. This happens to be 45,500 barrels per day. It is not profitable for the company to produce less than this amount. Similarly, the government has placed an upper limit on production of 50,000 barrels per day. This is in an attempt to conserve oil reserves for the future. Upon reflection; however, a practical upper limit on production can be specified. It is certainly folly to produce oil faster than it can possibly be pumped into an export tanker. Thus, an upper production limit is 45,875 is realistic because of physical restrictions.

Based upon the tanker loading rate, a minimum interarrival time can be specified. Again, common sense dictates that the tanker interarrival time should be at least as great as the time required to load a tanker. At the rate of 45,875 barrels per day, it takes 7.2 days to fill a tanker with 330,000 barrel capacity. To this the times required to hook-up and unhook the loading tanker must be added. Thus, the minimum tanker interarrival time examined was 7.5 days.

Finally, oil capacities must also be specified. Each loading tanker has a capacity of 330,000 barrels. The storage facility has a capacity of 1,000,000 barrels. Also, a minimum oil level is required: 150,000 barrels. The tank batteries contain a small amount of in-process storage. However, this is negligible, and was not specifically included in the analysis.

IV. MODEL DESCRIPTION

In this section a discussion of the SLAM simulation model used in the analysis of the oil company operations will be presented. The model was developed using a combined network, discrete-event, and continuous framework.

The network portion of the model was used to generate arrivals of tankers to be loaded. In addition to generating arrivals the network segment of the model initiated and terminated loading of the tankers. The problem of scheduling tanker arrivals was addressed in this portion. To measure the performance of a given arrival schedule, statistics were collected on the time a tanker spent waiting for loading. This was important since a long tanker waiting time is cost ineffective.

The discrete-event portion of the model controlled the flow of oil from the wells to the tank batteries and from the tank batteries to the storage facility. Also, the flow of oil to a tanker being loaded was controlled from a discrete event subroutine. The amount of oil in the storage facility was used to establish the operating policies for the amount of oil flowing in the system. If the level of oil in the tanker reached eighty percent of capacity the flow of oil from the wells to the tank batteries was reduced by twenty percent. Similarly, if the level of oil in the tanker rose to eighty-five percent of capacity then the flow of oil was reduced to seventy percent of normal. The flow of oil from the wells to the tank batteries was reduced by ten percent for each five percent increase in the level of oil in the tanker beyond eighty percent. This policy was used until the level of oil in the storage tanks reached ninety-five percent of capacity at which point the flow of oil from the wells was reduced to zero.

To prevent the oil in the storage facility from falling below the critical point of 150,000 barrels a policy similar to the overflow policy was used. The underflow policy took effect when the level of oil in the storage facility reached twenty five percent of capacity. Then with each drop of five percent in inventory the production rate at the wells was increased by ten percent.

The continuous segment of the model employed three rate equations and three difference equations. The rate equations corresponded to the flow of oil from the wells to the tank batteries, from the tank batteries to the storage facility, and from the storage facility to a tanker being loaded. The difference equations represented the amount of oil in the tank batteries, the storage facility, and in a loading tanker.

V. ANALYSIS OF RESULTS

This section presents the initial results of the simulation model. The model of the oil exporting operations was run for 365 days. The primary statistics of interest were the average wait for loading and the average amount of oil in the storage facility.

In order to determine an appropriate schedule of arrivals of tankers, the loading operations must be examined. The process of loading a tanker with oil has a lower bound of seven days. Consequently, it would be universe to have ships arrive in intervals of less than seven days. It was determined that the arrival of ships could best be described as a skewed triangular distribution. The lower bound was given as six days and the upper bound was given as twelve days. The mode of the distribution was given as eight days.

The results obtained using the aforementioned triangular distribution were quite good. The average wait for loadings was only 3.5 hours. This is a desirable result since the exporter would prefer to always have a ship ready for loading. The arrival distribution was tested with three other sets of parameters and did not produce better results.

The average amount of oil in the storage tanker over the year was 681 thousand barrels. The level of oil in the storage facility reached a maximum of 932 thousand barrels while the minimum amount of oil in storage was 493 thousand barrels. These statistics show that on the average there was enough oil in the storage facility to fill two tankers. Also, the overflow policies were necessary to keep the storage facility from filling up. However, the underflow policies were not needed. The average flow of oil from the wells was 37.5 thousand barrels per day.

VI. CONCLUSIONS AND RECOMMENDATIONS

The oil exporting facility is not using their resources to capacity. They are incurring large inventory costs by carrying an average of 681 thousand barrels of oil in the storage facility. This high level of inventory is causing the production rate at the wells to drop below the breakeven point of 45.5 thousand barrels per day.

In order to alleviate the problem of high inventory and low production rates, two alternatives are presented for investigation. First, the storage facility could be modified to fill two tankers simultaneously. A similar alternative would be to have two storage facilities with a somewhat smaller capacity.

Of course,the preliminary results only scratch the surface of required analysis. Various combinations of storage facilities, their cost, multiple tanker arrivals, etc. Must yet be considered. Also of importance is the oil flow alteration policy. These and many other issues are of importance and remain to be examined.

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