A LINEAR MATHEMATICAL MODEL TO OPTIMIZE BUYING, SHIPPING AND STORING OIL FIELD TUBULARS

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Scope and Method of Study: This study develops a mathematical model to assist oil companies in buying, shipping, and storing tubulars at the minimum cost. The equations developed were to utilize existing information which the materials sections of these companies were presently collecting. The model to be developed must be solvable using existing computer codes.

Findings and Conclusions: The model developed in this report can be solved using a branch and bound technique for linear models. The size of the model is potentially very large. Through reasonable constraints, the size of the model can be reduced to a size easily solved on any large computer system. In addition, the model can be adapted to commodities other than tubulars.

ADVISER'S APPROVAL J. Scott Turner

A LINEAR MATHEMATICAL MODEL TO OPTIMIZE BUYING, SHIPPING AND STORING OIL FIELD TUBULARS

Report Approved:

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PREFACE

This report is concerned with the derivation of a mathematical model. This model was constructed to assist the procurers of tubulars so that the time spent deciding which supplier from which to buy could be done by a computerization of this model, thus freeing up their time for other endeavors. The model was built so that it was linear, and thus could be solved using existing computer codes.

The author wishes to express his appreciation to his adviser, Dr. J. Scott Turner, for his guidance and assistance in developing this model. Appreciation is expressed for the help of Don Ryan. The idea of this model was his. Mr. Ryan's guidance in where background material on tubulars might be found saved many hours of looking.

Special thanks are given to my wife for her support and typewriter throughout this effort.

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NOMENCLATURE

CMW^R	the minimum shipping weight per rail car which the railroad will bill the buyer. Any actual weight less than this will result in the minimum weight being used to figure the freight bill.
CMW^T	the minimum shipping weight per truck which the trucker will bill the buyer. Any actual weight less than this will result in the minimum weight being used to figure the freight bill.
E	the multiplier which depends on market conditions and the type of supplier.
F	the fixed cost associated with either owning or leasing a warehouse.
G	the minimum number of suppliers the model is to consider.
IS	the holding cost for tubulars; it is the difference between the increase or decrease in their sales value and the cost of money tied up by holding them.
ISW^R	the incremental weight shipped by rail car above the minimum shipping weight (CMW^R).
ISW^T	the incremental weight shipped by truck above the minimum shipping weight (CMW^T).
M	a large number used to force an integer to zero or one.
MT	the buyer's mill allocation in tons.
MW^R	the maximum shipping weight per rail car.
MW^T	the maximum shipping weight per truck.
P	the maximum weight percent which can be purchased from a supplier.
TR	the tubular requirements for each destination point (well or warehouse day-to-day well workover needs).

TS	the available tubulars from a supplier.
W	the weight conversion factor to convert feet of tubulars into either pounds, hundred weight, or tons.
X	the feet of tubulars moving through the model.
a^R	the cost per unit weight to ship tubulars by rail between the source and destination.
a^T	the cost per unit weight to ship tubulars by truck between the source and destination.
b	the variable cost per ton to store tubulars.
c	the cost per foot to purchase tubulars from a source.
y^F	a zero or one integer; it is zero if a warehouse location is not used, and one if it is used.
y^{FR}	the fractional value of a shipped rail car to complete an order.
y^{FT}	the fractional value of a shipped truck to complete an order.
y^{PR}	this counts any fractional rail car as a full one so the fixed shipping cost can be charged.
y^{PT}	this counts any fractional truck as a full one so the fixed shipping cost can be charged.
y^R	the number of whole rail cars shipped.
y^S	a zero or one integer; it is zero if a source is not bought from and one if it is.
y^T	the number of whole trucks shipped.

Subscripts

d	the destination of the tubulars; it is for either a well or for a warehouse day-to-day well workover stock.
i	the supplier's geographic location.
j	the warehouse identification number and location of the buyer's warehouse.
k	the identification number for the type of tubular.
s	supplier identification number.
t	time period.

CHAPTER I

INTRODUCTION

The oil game is a series of wells drilled in the hope of finding those ever-increasing valuable commodities: oil, gas and gas liquids. Oil wells can cost from thousands of dollars to well into the millions of dollars. As an example, a North Sea exploratory well can run from six to twelve million dollars. With this amount of money being expended, the price of a length of pipe to case a well would hardly seem to make any difference. However, pipe for a deep offshore well might run $700,000. This is a considerable sum when a company may be planning twenty-five wells in a given area. In the year 1979, Phillips Petroleum Company bought twenty-one million dollars' worth of casing and tubing for its domestic operations. This figure is a net number, since many wells drilled are owned by several different partners. This twenty-one million dollars represents over twenty-three thousand tons of pipe. With this kind of pipe movements, a logical development would be a mathematical model which would assist the purchasing and materials departments in trying to optimize buying and shipping tubulars (casing and tubing), while minimizing holding costs.

Trying to schedule the buying, shipping, and storing of tubulars is comparable to hitting a moving target. Not only is the business extremely volatile, but your own people cannot always tell you if a certain well is to be drilled until the last minute. At this writing, tubulars were getting difficult to acquire. Demand has not overwhelmed supply, but the trend is in that direction. This puts an additional burden on the materials and purchasing departments.

The people who oversee buying, shipping and storage of tubulars have several constraints. They must order pipe three months ahead of time to ensure delivery and obtain the best price. These orders are based on the current drilling schedule and the past experience these people have. One basic problem is that drilling schedules change. These changes occur due to drilling rig availability and other wells currently being drilled. A new discovery may cause five unplanned wells to be drilled, whereas a dry hole in an expected producing area may cause five wells to be cancelled. Furthermore, steel mills only roll certain types of tubulars at certain times during the year. Thus, the buyer's schedule must match the mill's schedule. Finally, the tubulars must be shipped from the supply sources to the buyer's warehouse. From the warehouse, the tubulars are shipped to the wells as needed. Should the schedule permit, the tubulars may be shipped directly to the wells from the mill. All these considerations cause the movement of materials, in this case limited to casing and tubing, to be a constantly changing puzzle. An interactive model would hopefully assist these people in making further use of existing resources.

Oil field tubulars are one of the many items used in producing oil and natural gas. These tubulars are the conduits which allow oil and gas to be brought to the surface. Oil field tubulars as discussed here are limited to casing and tubing used in wells drilled by the oil industry. To a layman, these tubulars look like pipe a plumber might use, except the pipe has an unusual thread design capable of sealing the pipe joints and thus holding a great deal of pressure. Furthermore, the pipe itself may have a complex metallurgy to withstand the corrosive environment, which includes hydrogen sulfide (H_2S), which is quite toxic and will cause hydrogen cracking of steel by interfering with its molecular makeup, and carbon dioxide and water, which form a weak acid and literally eat holes in the tubulars.

Oil field tubulars are a specialized section of the steel industry. Tubulars are made in the United States, Canada, Japan, West Germany, France, England, and other countries throughout the world. Due to the large role Americans have had in the oil industry, most tubulars are manufactured to API (American Petroleum Institute) specifications. Due to the changing nature of the oil industry and the differing life of tubulars, non-standard tubulars can be found throughout the oil industry, particularly in the older oil field. Today, as United States dominance fades, pipe is being produced in metric sizes. The following discussion will give the reader a partial list of the wide variety of tubulars available.

Tubulars can be purchased in three different ranges: one, two, and three. Range one tubulars are sixteen to twenty-five feet in length, with 95% of a car load having a minimum length of eighteen feet. The maximum variance is six feet. Range two tubulars are twenty-five to thirty-four feet in length, with 95% of a car load having a minimum length of twenty-eight feet. The maximum variance is five feet. Range three tubulars have a minimum length of thirty-four feet with 95% of a car load having a minimum length of thirty-six feet. The maximum variance is six feet.[1]

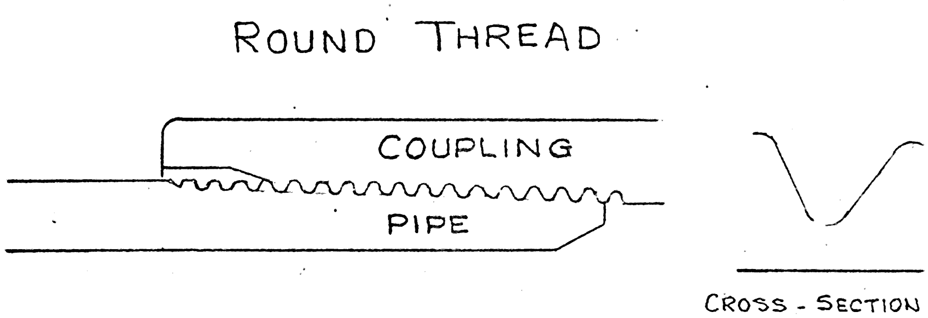
Tubulars also come in a variety of steels with different tensile strengths. Common grades are H-40, J-55, N-80, P-110, S-95, C-75 and V-150. The steel's properties, combined with the tubulars' thickness and diameter, determine the tubular's burst, collapse, and yield points.

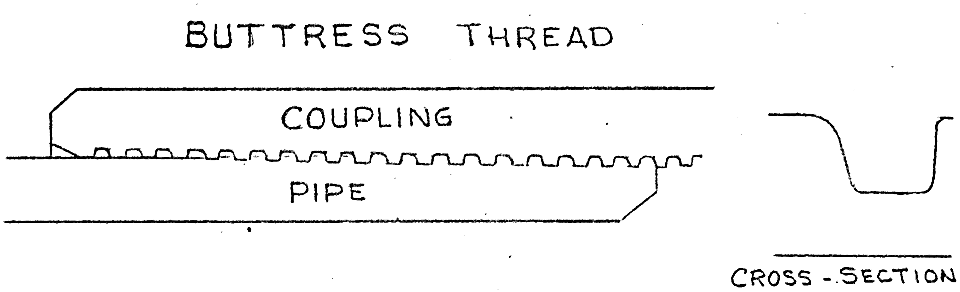
The burst point is simply where the internal pressure is high enough that the pipe splits open. The steel industry has conducted numerous tests to predict the various properties like burst, collapse, and yield for each type of tubular. These tests are condensed into useable equations. For grade J-55, in sizes smaller than 9 5/8", the formula is $P=1.6\ Ym\ (t/D)$, where P is the minimum test pressure, Ym is the minimum yield strength, t is the wall thickness and D is the outside diameter. This formula has a built-in safety factor.[2] Collapse occurs when the external pipe pressure exceeds the collapse resistance of the pipe and the internal pressure. The collapse pressure is also a function of yield strength, wall thickness and outside diameter. Finally, the yield strength is important, because in a well, as pipe is run into the well, the top joint of pipe supports everything below it. Thus, if the weight exceeds a certain amount, the pipe will stretch and break. For an appreciation of the amount of stretch in pipe, without any damage to the pipe, a 10,000-foot string can be stretched forty or fifty feet and rotated so that the top of the string is turned ten turns more than the bottom in an attempt to free pipe stuck while drilling.

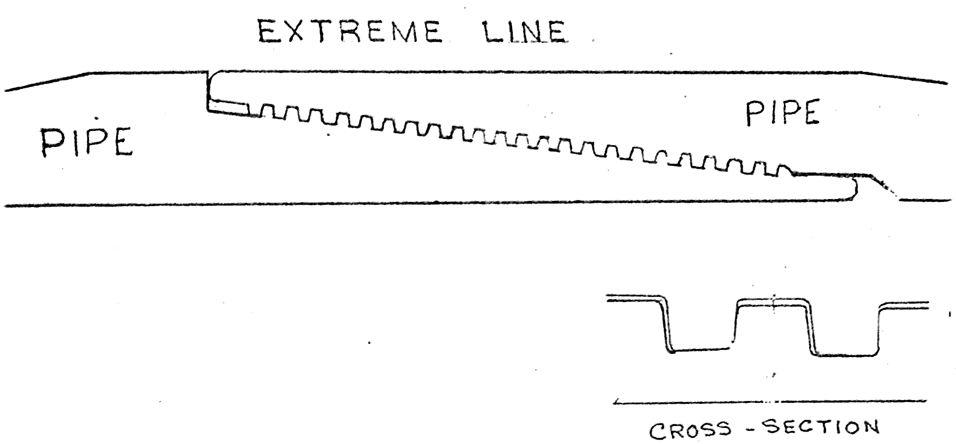
Another factor in the selection of tubulars is that of the tool joints. Tool joints are simply where the pipes are connected to each other. The tool joint can have two pieces of pipe which screw into a coupling, or one piece of pipe can screw into another (extreme line tool joint). Each type of tool joint has several thread types. For couplings, round or buttress threads are normally used. For extreme line, there are a variety of threads, depending on the pressure requirements (Figure 1). The combination of these two parameters (threads and tool joints) when combined with other special types of threads

FIGURE 1

EXAMPLES OF THREADS AND TOOL JOINTS







makes for quite a large number of combinations. As an example, a round thread will have a rounded crust and root V-type 8 pitch threads tapered 3/4" per foot on diameter. A buttress thread has a special buttress form of five pitch threads tapered 3/4" per foot on diameter.[3] Again, depending on the thread, type of joint, steel properties, the pipe thickness and diameter, the tool joint has only so much strength. Two joint properties are typically calculated: the fracture strength and the pull out strength. The fracture strength is the amount of force a joint can withstand before it parts. The pull out strength is the force a tool joint can undergo before the joint is pulled apart at the threads, that is, the pipe threads cannot hold the pipe together. Tubing joints are different from casing joints to facilitate repeated make up and unscrewing of the pipe as it is pulled out of the well for well workovers. Both threads and joints are different from casing. In particular, tubing can be upset or non-upset. Upset tubing is where the wall thickness has been increased at both ends of the pipe, so the wall thickness is the same as the rest of the pipe after the ends are threaded.

With the standard types of casing and tubing, the person designing the casing and tubing strings must analyze well conditions and then specify the tubulars for the job. A casing or tubing string is designed based on collapse, burst and yield properties of the pipe. These are set by the type of fluid environment (certain types of steel are not suitable for H_2S or other environments) and the quality of fluids to be lifted out of the well (that is, due to friction loss, certain diameters are required). In any design, one or more of these three parameters will control. An example might be a hypothetical 10,000-foot casing string. At the bottom of the well, collapse might dictate the kind of tool joints and pipe thickness. Higher up the hole, burst may be the overriding factor. Finally, at the top of the hole, the pipe may need to be thick and the type of joint changed because of the sheer weight of the casing string.

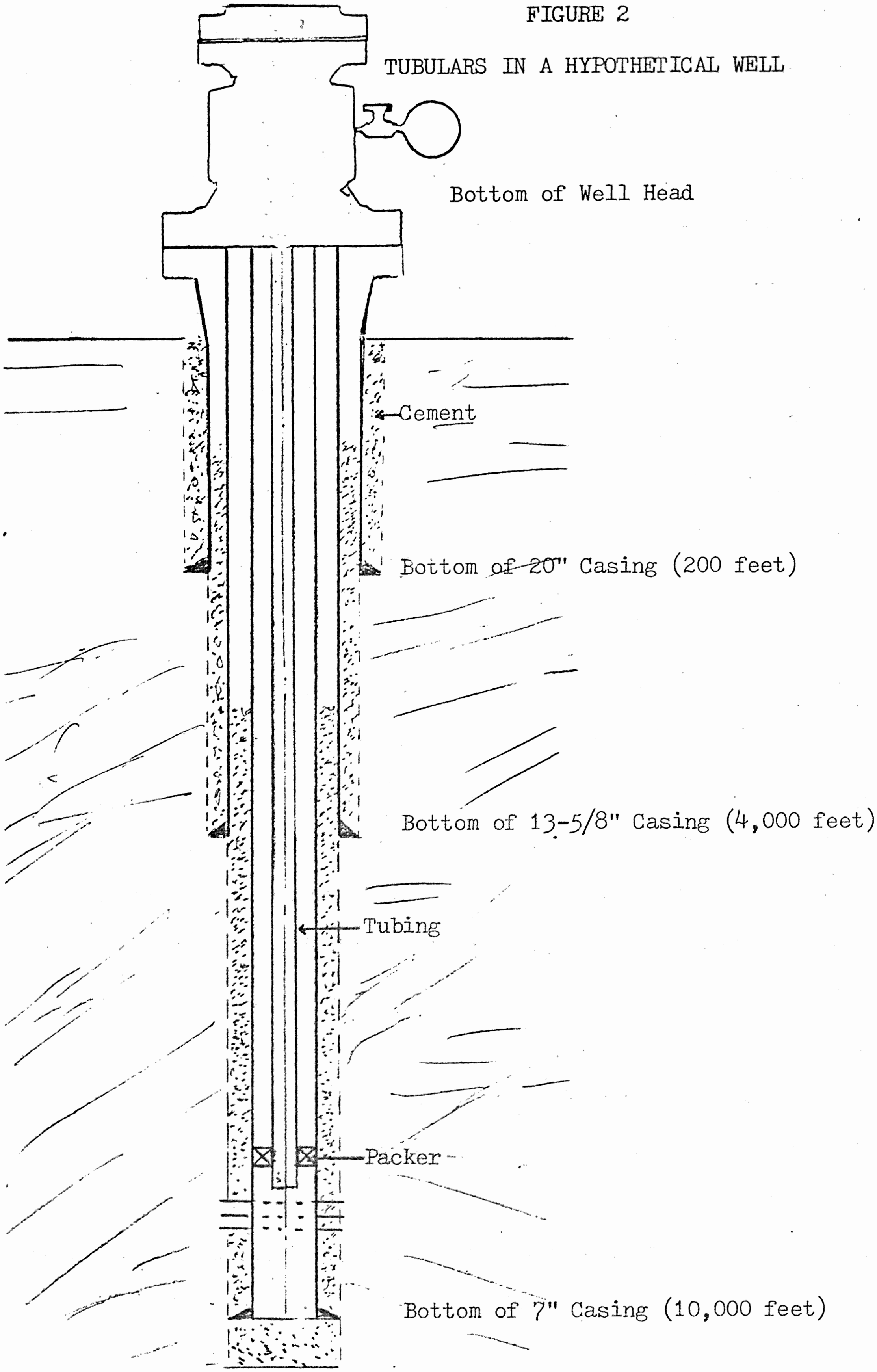
A diagram of a hypothetical well is shown in Figure 2. Twenty-inch casing is run to two hundred feet. An intermediate string of 13 5/8 - inch casing is run from the surface to a depth of four thousand feet. The innermost casing string or production string is run to ten thousand feet. Inside the production string, a tubing string is run in which the oil and/or gas will flow to the surface. The packer in Figure 2 merely keeps the oil and gas out of the annular space between the tubing and the casing. Note that the casing is cemented to the rock around the well bore, while the tubing is not. Thus, should the tubing become damaged due to corrosion or some other factor, it can be replaced, whereas the casing cannot be pulled out of the well and replaced. This is the reason production flows up the tubing and not the casing.

At the other end of the spectrum is the source of the tubulars. Tubulars can be purchased directly from the mill, by placing an order through a jobber, from the jobber himself, or from a local supply point. Basically, two conditions prevail in the world of tubulars. The first is where supply exceeds demand, the second is where demand exceeds supply. The oil industry is dependent on a number of external factors, including government policy and exploration wells finding new oil fields. Therefore, tubular markets continually change with respect to supply and demand.

The steel industry acts in a fairly predictable manner. When supply exceeds demand, prices are lowered, terms of sale are extended, and freight is equalized. Freight equalization refers to a supplier charging

FIGURE 2

TUBULARS IN A HYPOTHETICAL WELL



a customer for freight from the delivery point to the closest supply point. This means that if the supply points are Chicago and Houston, and the destination is New Orleans, the Chicago supplier will charge his base price plus the freight costs from Houston to New Orleans. The difference in freight costs from Chicago to New Orleans and Houston to New Orleans would be absorbed by the seller. As demand approaches supply and passes it, terms become stricter, freight equalization is dropped, and prices may rise.

The supply network for tubulars begins at the steel mill. Here, the tubulars are made at a scheduled time according to the mill's rolling schedule. The buyers of tubulars and the sellers of tubulars interact, so that the mill advises when it is going to roll each type of tubular, and the buyer responds and contracts for so much of the roll. If orders exceed the roll, they are applied to the next scheduled roll. When actually ordering tubular, the customer must buy through a jobber. The jobber buys at a 6% discount from the mill. The tubulars are shipped directly from the mill to the buyer. The mills also have pipe storage points located around the country. These are bought from in the same manner as the mill. The jobber buys not only for his customers, but also for himself. His purchases are for buyers who need smaller quantities, or who cannot wait on a mill's rolling schedule, but rather need the tubulars in a few weeks. In selecting a jobber to do business with, the buyer must consider size and reliability, because the jobber must be big enough to service the buyer's account. In addition, as supplies become hard to acquire, the jobber is counted on to perform. In short, a relationship has to be built, so that the jobber will come through when supplies get tight.

The buyer further protects his supply sources by not buying from the cheapest source alone, but by spreading his business around. By doing business with a number of mills, you have your foot in the door, and thus when demand exceeds supply and mills start to allocate tubulars, you stand a better chance of getting a mill allocation if you have been a good, steady customer.

Mills basically sell tons of steel. Thus, when allocations are given, the mill tells each buyer what his allocation in tons will be for the year. Mills can also refuse to sell pipe if they feel the pipe is being hoarded. An example might be a buyer wanting a large quantity of 30-inch casing. In this type of casing, only two mills might roll this kind of casing. The buyer wants the casing because he feels the market will tighten to the point where the casing cannot be purchased. Even though the buyer has an allocation, the mill may refuse to sell him the casing, because then no one else could drill wells requiring this kind of casing. The mill is not only trying to supply its customers, but it is also keeping companies out of the speculation market.

The final member in the supply network is the local store. The local store gets a price premium, ranging from 10% in times when supply exceeds demand to 20% when demand exceeds supply. The local store normally supplies small quantities of tubulars. The buyer normally purchases only a few pieces of tubing for remedial work (workover) on a well or part of a casing string due to a last-minute change in drilling plans. In contrast to the jobber who is located in the major oil areas, the local store is located in just about every small town in the oil field. Furthermore, the mill, jobbers, and local store supply a full range of oil field goods and not just tubulars.

There are several other sources of tubulars. Buyers sometimes sell tubulars when they feel they have no need for them. The buyer may supply some of his own needs as he abandons old wells. Tubing and some amount of casing can often be salvaged from abandoned wells. During the life of a well, the tubing requirements in the well may change as the well's flow rate and flowing pressure change. Thus, as tubing is changed out, it becomes available for another well. Thus, tubulars may be used in several different locations over their useful life.

The final segment of the tubular network is that of storage and transportation. As was stated earlier, the cost of freight is sometimes partially paid by the mill (freight equalization) so the mill can be competitive in price. With this exception, the buyer is normally responsible for shipping. There are three ways to ship tubulars, and in one shipment from source to destination, all three could be used. The means of shipment are by barge, rail and truck. Barge is the most limited in terms of locations it can service, while truck is the least restricted. In this paper, truck and rail only will be considered, since this accounts for almost all movements of tubulars within the continental United States. Unless the buyer does his own trucking of tubulars, the buyer will rely on a common carrier, that is, a railroad or trucking company. Both are regulated by the ICC, and thus their rates are published.

Trucking rates can either be based on an hourly rate or a distance rate. The hourly rate is used when transporting short distances. Presently, for trucks capable of handling 40,000 pounds of pipe, the rate is between $45 and $55 per hour for the truck and driver. The distance rates are based on mileage and weight ranges (Appendix A). Thus, for a five hundred mile haul, with a minimum weight of 30,000 pounds on the truck, the rate is $1.94 per hundred weight. This rate has been increasing. Over the last two years, the rate increases have been 7% in April 1978, 3% in April 1979, 3% in June 1979, and 4% in March 1980. The amount of weight trucks can haul varies according to state law. These laws are based on total (gross) weight of the truck and cargo. This means the truck can haul roughly 40,000 to 45,000 pounds.

Shipments by rail can be 80,000 to 100,000 pounds. Here again, the cargo weight is dependent on the track and weight of the rail car. The cost of rail service is negotiable, even though the rates are published. Once the rate has been negotiated between the buyer and the railroad, the railroad goes to the ICC to get it accepted and published (about forty-five days). If possible, railroads try to set their rates just below any other type of transportation. Furthermore, railroads would like their revenue-to-variable costs ratio to be around 1.5 to 1. Railroads price their services as a combination of cost of service and value of service. The value of service is a function of the alternative type of transportation. The cost of service is a function of product weight, density, packaging and product value. In negotiating fares with railroads, a similar route may be used, or a worksheet (Appendix B) is used to estimate the railroad's cost. The railroad shipping costs are broken into a number of categories in published materials available from the government. These books run two to three years behind, and thus the costs in the rate books are escalated using published escalation guides.

When shipping to the destination, timing sometimes permits the goods to be shipped directly from the supplier to the well. When this is not possible, the materials must be stored in a warehouse (storage yard).

These locations are centralized in the local region and are either leased or buyer-owned. Leased yards are typically owned by a trucking company, because they want to do the hauling. The charges vary from location to location, but some typical numbers are that storage costs are thirty-five cents per ton with a $300 month minimum. Loading and unloading are about fifteen cents per hundred weight. The yards can also perform pipe inspection, coating and other services for a price. The current price of thirty-five cents per ton storage is up from twenty cents twenty months ago and thirty cents twelve months ago.

In yards or warehouses owned by the buyer, charges for storage can be calculated a number of ways. It can be a percent of the purchase price, it can be direct wages plus an overhead allocation, or it can be charged as so many cents a ton. There is an indirect fixed cost related to the opportunity cost of the land and facilities owned by the buyer. If the buyer sells his own facilities and uses leased facilities, he can use the money for other purposes.

The last item necessary for the model to work is the idea that inventory costs money. This idea is valid as long as money costs more to use than the price increase in tubulars over the time the tubulars are in inventory. The cost of holding an inventory must be separated from the buyer's decision that since tubulars will be difficult to get later in the year, he will buy more. The buyer needs to know the holding cost, but at the same time he must have tubulars to stay in business. By knowing all the holding costs, he can then make his buying decisions.

The model to be developed in this paper incorporates buying, transporting, storage and opportunity costs. It will be built with the idea that both the buyer and the seller influence the marketplace. Thus, the model constraints are sometimes set by the buyer and sometimes by the seller. The model will attempt to incorporate opportunity costs, so in an accounting sense, the optimal solution will yield a cost higher than the actual billed cost. The model will, however, give an approximation of the true cost of the tubulars being used by the company.

FOOTNOTES

[1]Armco Oil Country Tubular Products Engineering Data, Armco Steel Corporation (Middletown, Ohio, 1966), p. A-1.

[2]Ibid., p. A-6.

[3]Ibid., p. A-1.

CHAPTER II

LITERATURE REVIEW

The initial intent of a literature search was to locate models which were either of a buy, store, or transport nature, or a combination of the three. After searching the relevant literature, none were found. In some respects, this is to be expected, since a model of this type would normally be generated for intra-company use. The search started with the computerized data files and ended in a search of relevant management science publications.

The initial search was done on the computer-based data banks. The search was undertaken using relevant key words. The following words were tried either by themselves or in combination with the others:

1) Model
2) Mathematical
3) Tubulars
4) Transportation
5) Shipping
6) Storage
7) Purchasing
8) Steel.

Key words are used by the computerized data set as a comparison against key words in the articles stored in its memory. When a key word the user selects corresponds to a key word in a stored article, the article name, author, abstract, date, publication, and other relevant data are put into an output file for retrieval by the user. Two data files were tried for this search. These were file ABINFORM on the Dialog system and file 75 on the Management Content system. These two files were selected from the available files as being most likely to contain management science-related literature. Some of the key words generated a number of computer responses, but after examination, no articles which were deemed relevant were found.

The literature search was then expanded to the libraries at the University of Kansas and Oklahoma State University. A search was conducted on magazines related to the management science field. As articles useful to this paper were located, the search expanded using the bibliographies accompanying the articles. The main emphasis in the literature search was toward articles written in the last ten years. It was felt that computational equipment capable of solving large networks had advanced so much in the last ten years, that articles written prior to ten years ago would be useful only for background material or theoretical approaches. In the author's opinion, mathematical models and computer codes are a response to the availability of large computers, that is, industry pays for only what it can utilize.

Early work done on network models, that is, a series of algebraic equations which describe a process, can be found in government-sponsored research published in the Naval Research Logistics Quarterly. Articles on various aspects of networks appear regularly in the late 1940's and early 1950's. The ability to solve these problems in a straightforward manner was enhanced by the introduction of G.B. Dantzig's simplex method. In recent years, literature on the network subject can be found in a number of magazines, including:

1) Operations Research
2) Mathematical Programming
3) Networks
4) Management Science
5) AIIE Transactions.

Furthermore, many books, theses, and reports have been written on the many aspects of networks. A listing of articles consulted can be found in the bibliography. Further background material was obtained from classes taken in the area of study and the texts used in these classes. These texts also appear in the bibliography. A few examples of the periodical literature available will now be discussed, in order to illustrate the type of information available. These are:

1) "Network Application in Industry and Government" by Fred Glover and Darwin Klingman in AIIE Transactions, Vol. 9, No. 4, December 1977;

2) "The Transhipment Problem" [sic] by Alex Orden in Management Science, Vol. 2, No. 3, April 1956;

3) "A Primal Method for Minimal Cost Flows With Application to the Assignment and Transportation Problems" by Morton Klein in Management Science, Vol. 14, No. 3, November 1967;

4) "On Some Techniques Useful for Solution of Transportation Network Problems" by N. Tomizawa in Networks, Vol. 1, Issue 2, 1971.

The first article by Drs. Glover and Klingman is a general overview of network applications. The authors cover transportation problems, file aggregation (data bases) applications, transshipment problems, production planning and distribution applications, fixed charge, plant location, integer and generalized assignment models. In each case, the authors describe the problem, the type of data required, the variables, and then make a statement as to the computer time necessary to solve the problem.

The article by Alex Orden, while dated, was selected because the subject in his article had a direct impact on my proposed research topic. The model constructed in this paper will include transshipment capabilities. The author builds on the basic transportation mathematical models, which can be solved using the simplex methods of G.B. Dantzig. Orden adds the capability to have flow (which could be raw materials, finished goods, or other items) locations (like warehouses) to which the originating location ships, allowing these transshipment points to make the actual shipments to either another transshipment location or the final destination. The article, written before the advent of really large computers, keeps to the conceptual level and goes through an example to demonstrate the technique.

The article by Morton Klein is concerned with the addition to the existing techniques of another technique which can solve both assignment and transportation problems. The article defined a particular transportation problem and proceeded to introduce an algorithm to solve it. The article is of limited use to the model constructed in this report, since the model in this report can be solved by a canned program without regard to the internal workings of the computer program. The article is indirectly useful in that it does give further insight into the network models.

The final article by N. Tomizawa is another algorithm to solve transportation networks. The technique for the multisource-multisink network builds from a subnetwork to the full network. The article is valuable not for the solution technique, but for its insights into network problems and their solutions. The solution technique would be one to consider, if a computer software program were to be written to solve the network problem constructed in this paper.

The four articles just mentioned, together with the others researched, are for the most part concerned with coming up with a better algorithm to solve problems with ever-increasing speed, to minimize computer time.

While the techniques may help in ensuring the proposed model covers all aspects of the problem, none address the problem of applying the network concept to a large problem.

CHAPTER III

THEORY/RESEARCH DESIGN

The purpose of this paper is to develop a mathematical model to solve a tubular supply and distribution problem. As such, there is no real hypothesis; rather, the research design will be to obtain a working model which is capable of handling any size tubulars problem and which, at the same time, can be solved on a computer using a canned computer program. This paper assumes that necessary computer algorithms exist which can solve this model. The model will be laid out in this chapter of the paper and will be expanded upon using a simplified example in the next section.

The idea for this model was born out of the reality that a large organization like Phillips Petroleum Company does not have a model to optimize its materials buying, distribution, and storage functions. At present, work is just beginning to develop such a system. This is not to say that Phillips does not keep track of its inventories; rather, the company does it in a manual manner. What is proposed here is a model which can interface with the materials handling sections of the company to ensure timely delivery of materials, while at the same time minimizing materials costs to the company. This cost minimization includes the cost of buying, shipping, and storage of the materials. It also includes the cost of money tied up in company warehouse facilities and tubular inventories.

Due to the tremendous amount of externalities, this paper does not purport to replace manpower by a computer; rather, the computer will assist the materials man in making the proper purchasing choices.

The model being proposed consists of three distinct functions: buying, shipping and storage of tubulars. All three are tied together within the model, because each is dependent upon the other parts. The model is a series of supply-demand requirements, each having a cost associated with it. For the proposed model, the cost function is a cost minimization, since no revenues will be discussed.

The cost minimization for the model will, for convenience, be broken into several parts. The cost function for the purchase of the tubulars is

$$\sum_{k}\sum_{t}\sum_{s}\sum_{i}\sum_{j} c_{k,t,s} \; (1 + E) \; X_{k,t,s,i,j} \; , \qquad (1a)$$

where c = cost per foot of tubulars,

X = feet of tubulars required,

E = a factor which depends on the market conditions and type of supplier,

k = type of tubular; an identification number,

t = time period,

s = supplier identification number,

i = supplier location,

j = warehouse location of the buyer.

As with most markets, the tubulars market is dynamic. The price and terms of sale are constantly changing. For this reason, prices will be allowed to fluctuate over time. The tubulars market shows some typical signs that supply and demand truly influence the price. As demand exceeds supply, prices increase, and terms become more onerous. After the 1973-1974 oil price increases, drilling increased and tubular became impossible to get, and prices increased accordingly. A perceived shortage can also drive up prices, because everyone is buying tubulars for future use when they think tubulars may not be available.

Price is basically a function of weight of the tubulars; therefore, price may either be in terms of dollars per ton or dollars per foot. Tubular prices are also dependent on the type of steel used, the range of tubulars purchased and other factors. The E factor is a price multiplier to reflect the type of supplier and the market conditions. As the source, the mill is the cheapest, followed by the jobber and finally the local store. The type of tubulars, k, deals with the diameter, weight per foot, type of steel, length of pipe, and type of pipe joints and threads. In this model, k is an identification number which represents several parameters. k could be expanded if desired into k1, k2, k3 . . . kn, each of which would represent a property. Thus, X_k would become $X_{k1,\ k2,\ k3...kn}$.

The time period can be any the user wishes to specify. One example might be that t is in weeks for three months, two weeks for the next three months, and then by month for the next six months. Timing is important, due to the delivery date. In buying from steel mills, a lead time of two or three months is required. Jobbers require a few weeks and local stores a day or two. However, local stores cannot supply a large demand and are also the highest in price.

"s", the supply identification, is a unique number given to each supplier. This can be a mill, jobber, local store, or even another company warehouse. Since this model is continually updated, t = 1 is the time period starting the date the model is run. Therefore, as conditions change, a well may not be drilled and at a warehouse location, tubulars become available for use elsewhere.

"j", the warehouse location, is generally the recipient of tubulars. If the timing is right, tubulars may be shipped directly from the source to the well. This possibility is one reason the model considers time.

The second part of the cost minimization function is that of transportation. The function is composed of both fixed and variable costs. The function is tied to constraint equations (9), (10), and (11) so that the shipping weight is broken into two parts: the minimum shipping weight which the buyer is charged for, whether or not his load weighs that much, and the incremental weight over this minimum weight. The cost functions are:

$$\sum_t \sum_s \sum_i \sum_j (CMW^R_{tsij}) a^R_{tsij} (y^R_{tsj} + y^{PR}_{tsj}) + \sum_t \sum_s \sum_i \sum_j (CMW^T_{tsij}) a^T_{tsij} (y^T_{tsj} + y^{PT}_{tsj}) \quad (1b)$$

$$\text{and} \quad \sum_t \sum_s \sum_i \sum_j a^R_{tsij} (ISW^R_{tsj}) + \sum_t \sum_s \sum_i \sum_j a^T_{tsij} (ISW^T_{tsj}) \quad (1c)$$

where (1b) is the fixed cost and (1c) is the variable cost function. The minimum cost which the buyer is charged for is based on the fact that, loaded or empty, the truck or rail car costs something to transport. Therefore, while the rates are based on a unit weight, a minimum weight is assumed for billing purposes if the load being shipped is less than this minimum weight. CMW^R and CMW^I represent this minimum weight limit for rail cars and trucks, respectively. a^R and a^T represent the cost per unit weight of shipping by rail or truck from supply source s to warehouse j during time period t. ISW^R and ISW^T represent the difference between the actual shipping weight by rail or truck and the minimum shipping weight. Both ISW^R and ISW^T are greater than or equal to zero. y^R and y^T represent the number of full rail cars or trucks shipped. y^{PR} or y^{PT} are a zero or one variable, which accounts for any partial rail cars or trucks being shipped.

As demand and supply fluctuate, sellers (mill) must make concessions when mill capacity exceeds demand for tubulars. The concession in the shipping area is that tubular mills will freight equalize with the closest mill to the destination, that is, the buyer can buy from any mill, but pays the shipping cost from the closest mill. An example could be that mills in Texas and Colorado are both vying for an order for a well in Louisiana. Under freight equalization, the Colorado mill would pay the difference in shipping cost to ship from Texas to Louisiana and Colorado to Louisiana. As demand catches up with supply, this concession is dropped and the buyer must pay the full freight cost from the mill to the destination. Due to the regional location of jobbers and local stores, freight equalization occurs only at the mill supply level. To handle freight equalization, the i subscript no longer represents the location of supply source s. Instead, it is the location of the closest mill to the destination of the tubulars warehouse j.

Transshipment between warehouse locations is considered only during time period one. In reality, it is possible during each time period, except this model assumes that every destination is serviced by only one warehouse location. Both shipping and storage are on a weight basis, as the tubulars for any given destination should always flow to the warehouse with the lowest combination of these two costs. If more than one warehouse is to service a given destination, the model would have to be expanded to handle this.

Transshipment is allowed in time period one by assigning any warehouse with inventory a supply identification s and a location i. This allows the inventory to flow to other warehouse locations. This is needed only in time period one to allow for changes made since the model was last run. The model will seek a minimum inventory level, since the model is controlled by a cost minimization function. Thus, inventory adjustments are needed only when well drilling schedules or the tubulars needed for day-to-day well workovers change. These changes require that the model's input data be altered to reflect these changes and that the model be resolved. The inventory is given a purchasing cost of zero, so that transshipment is controlled by shipping, storage, and holding costs.

Tubular storage is the third part of the cost function. Storage contains both a fixed and a variable cost element. The function

$$\sum_j F_j y_j^F + \sum_j b_{tj} \left[\sum_k \sum_{t=1}^{t} \sum_s W_k X_{ktsij} - \sum_k \sum_{t=1}^{t} \sum_d W_k TR_{ktjd} \right] \quad \text{for } t = 1,2\ldots n \qquad (1d)$$

represents the sum of the fixed cost, plus the variable inventory charge times the difference between the tubulars purchased and on hand at the beginning of the period and the tubulars actually used.

The first term $\sum_j F_j y_j^F$ is the fixed charge for using a warehouse location. The charge is not time-dependent, because, if the location is needed, it must be reserved for the time frame the model is run over. Two types of fixed charges are possible, one for a leased location and one for a buyer-owned location. In the situation where the buyer leases a warehouse location, the facility is typically owned by a trucking company, because they can provide a total service. They can store and transport the tubulars. For the buyer-owned warehouse locations, the buyer's fixed cost represents the opportunity cost of having his money tied up in the facility. In a rapidly rising real estate market, the fixed cost could become negative because the facility may be a good investment. Of the two variables, F represents the fixed cost, and y^F has a zero or one value. y^F is zero if the location is not used during the time span of the model.

The second term is the inventory in location j at time t. b_{tj} is the variable cost element in dollars per ton per time period for the time period t and location j. The two terms in the bracket represent the inventory level on a time period-by-period basis. The first part $\sum_k \sum_{t=1}^{t} \sum_s W_k X_{ktsij}$ represents the sum of all tubulars bought for location j from all the supply points. The number of time periods to sum over depends on which period the variable cost is being calculated. The subscript i is merely a place holder in this term used for clarity. The next term $\sum_k \sum_{t=1}^{t} \sum_d W_k TR_{ktjd}$ represents the cumulative outflow from location j to destination d for the number of time periods specified by t. The inventory level at t=0 is contained in the first of the two terms in the brackets. Any inventory on hand when the model is run is considered a supply point for one time period. TR is the tubular requirement for each destination d defined by equation number (2).

The final term in the cost function represents the holding cost for tubulars. By buying tubulars, money is being tied up which could be used elsewhere. Thus, the term represents an opportunity cost. The term represents the increase in value of the tubulars during the time period, less the cost of the money which is tied up in the tubulars. Both parts are time-dependent, as are most prices in this model. Thus, the model's coefficients can be generated from a time series, or, if the materials people are experienced, their best guess would probably be the best estimate.

The function

$$\sum_k \sum_j IS_{ktj} \left[\sum_{t=1}^{t} \sum_s X_{ktsij} - \sum_{t=1}^{t} \sum_d TR_{ktjd} \right] \quad \text{for } t=1,2\ldots n \qquad (1e)$$

represents the holding cost times the purchases of tubulars , less the uses of tubulars. The first term IS is the change in sales value of type k tubular during time t at location j and the cost of money tied up in the inventory. The beginning inventory is in the first term in the brackets. The first term in the brackets represents all purchases from supplier s to warehouse j summed from t=1 to t=t. The subscript i is used as a place holder. The second term is the outflow from warehouse j to destination d. Again, the term is summed over the same number of periods.

The constraints in the model represent either supply and demand considerations or requirements which must be fulfilled. The subscripts used in the constraints are the same as those in the cost minimization function. All subscripts are carried throughout the model, even though some are superfluous in a particular equation.

The first constraint is based on the requirement that the quantity of tubulars used by a warehouse (for day-to-day well workovers or sent to wells being drilled) must be less than the quantity of tubulars purchased (and shipping in from another warehouse in time period one) for the warehouse. The equation is:

$$\sum_{t=1}^{t} \sum_s X_{ktsij} - \sum_{t=1}^{t} \sum_d TR_{ktjd} \geq 0, \quad \text{for all } k\ (k=1,2,\ldots n) \text{ in each time period } t=1,2,\ldots n, \text{ for each warehouse location } j=1,2,\ldots n. \qquad (2)$$

This equation checks each time period for each type of tubular (k), such that the amount transshipped from another (supplier) warehouse in time period one plus the amount purchased from all suppliers is more than the amount used. Every time this model is run, the start date is updated to the current time. Should conditions change, present inventories in the warehouse locations may need to be moved to another location for better utilization. Thus, the model assumes the beginning inventory is zero, because any inventory becomes a source "s" available for shipping in time t=1 with a tubular price "c" equal to zero.

Tubular mills roll according to a fixed schedule. Accordingly, the quantity purchased cannot exceed that which the mill is willing to sell to a given buyer.

$$\sum_{j} X_{ktsij} - TS_{kts} \leq 0$$ for k=1,2,...n in each time period t=1,2,...n for each s=1,2,...n. (3),

where TS is the available tubulars of each kind, available in time t from supplier s. This equation applies to all suppliers, because for the jobber, local store, and any mill warehouse stock, the ultimate source is the mill. Thus, each source is limited by the chain as to the quantity which it can purchase for resale . Furthermore, in deciding the quantity the buyer may purchase from them, each supplier must consider its relationship with the buyer. This buyer-seller relationship is a concern the buyer must consider when selecting his supply sources. As previously indicated, the buyer needs a dependable supply, particularly when the market demand exceeds supply and tubulars become scarce. In addition, several supply sources are needed, because not all suppliers carry all types of tubulars. This is particularly true when the buyer needs a large diameter (twenty-inch casing or larger) tubular, a special steel type, or a special thread or tubular joint.

Tubular mills allocate their capacity on a tons per period basis. Here the period may be three, six, or twelve months. When supplies exceed demand, this equation does not constrain the buyer. As demand exceeds supplies, mills put their customers on a smaller and smaller allocation basis. For this reason, mill-buyer relations are very important. The equation

$$\sum_{k}\sum_{t}\sum_{j} W_k X_{ktsij} - MT_s \leq 0 \quad \text{for } s=1,2,\ldots n \qquad (4)$$

limits the tubulars purchased over the allocation period to the mill allocation in tons (MT) which the buyer has from each mill. Depending on the buyer's needs, either the mill's allocation, equation (4), or the mill's rolling schedule and tubular availability, equation (3), may limit the buyer's purchases from a given mill. W_k is a conversion factor to convert from tubulars in feet (X_k) to tubulars in terms of weight. In handling tubulars, tubular mills tend to think in terms of tons of tubulars, freight carriers in terms of pounds, and buyers in terms of feet. Thus, price quotes and requirement schedules may be in different units. W allows schedules to be used as they are, with the k subscript identifying the type of tubular in question.

Relationships between buyers and suppliers, particularly mills and jobbers, are based on past performance. For this reason, buyers limit their purchases from each mill and jobber, so they do not buy from only a few sources. Thus, when supplies become tight, the buyer has a relationship with several suppliers; so, if he gets cut off from one supplier, he still has others to whom he can turn.

The following equation limits the amount of tubulars purchased from any one source:

$$\frac{\sum_{k}\sum_{t}\sum_{j} W_k X_{ktsij}}{\sum_{k}\sum_{t}\sum_{s}\sum_{j} W_k X_{ktsij}} \leq P_s \quad \text{for all } s=1,2,\ldots n \qquad (5)$$

where P_s is a percentage selected by the buyer as the maximum percentage of tubulars, on a ton basis, which he wishes to buy from supply source s over the time frame the model is run. Since there are a number of mills and jobbers, the sum of all P_s could be 5 or 6, as some sources may not be used and others are not used to the maximum allowed percent.

To ensure that several sources are used, the following constraint is added to the model, so the minimum number of mills and jobbers used can be controlled by the buyer.

$$\sum_k \sum_t X_{ktsij} - y_s^S M \leq 0 \quad \text{for } s=1,2,\ldots n \qquad (6)$$

$$\sum_s y_s^S \geq G \qquad (7),$$

where y^S is a zero or one variable, M is a large number, and G is an integer which is the minimum number of mills and jobbers the buyer wishes to use. In equation (6), should the buyer purchase tubulars from supplier s, y^S is forced to a value of one. The value of G may become academic in a tight market, because suppliers may tell the buyer exactly what he can buy, or they may refuse to sell the buyer anything.

A similar equation to equation (6) is needed to determine which warehouse locations are used, so the fixed warehouse cost can be added to the cost function.

$$\sum_k \sum_t \sum_s X_{ktsij} - y_j^F M \leq 0 \quad \text{for } j=1,2,\ldots n \qquad (8),$$

where y^F is a zero or one variable. This equation forces y^F to be one if tubulars are stored or moved through location j during any time period over which the model is run. y^F is used in the storage function (1c). In this model, this equation is somewhat superfluous, because each destination point is serviced by only one warehouse location. Should the model be expanded to allow more than one warehouse to supply a given destination, this equation would take on more meaning.

The final set of equations works with the shipping function to identify the number of trucks or rail cars needed, maximizing the load each truck or rail car carries, thus minimizing shipping costs. The first equation is

$$\sum_{k} W_k X_{ktsij} - MW^R_{tsij}(y^R_{tsj} + y^{FR}_{tsj}) - MW^T_{tsij}(y^T_{tsj} + y^{FT}_{tsj}) = 0 \text{ for each } s,j \text{ combination and } t=1,2,\ldots n \quad (9),$$

where y^R and y^T are integers greater than or equal to zero, and y^{FE} and y^{FT} are greater than or equal to zero but less than one, and MW^R and MW^T are the maximum weights allowed in a rail car or on a truck by the freight carrier or by law. This equation divides up the loads from source s to warehouse j into full loads (y^R and y^T) and partial loads (y^{FR} and y^{FT}). Each full and partial load is charged a fixed shipping cost equal to the minimum shipping weight times the cost per unit of weight. To make y^{FR} and y^{FT} count as a whole truck in the fixed cost shipping function (1b), the following equations are used:

$$y^{FR}_{tsj} - y^{PR}_{tsj} \leq 0, \text{ where } y^{PR} \text{ is a zero or one integer,} \quad (10a)$$

$$y^{FT}_{tsj} - y^{PT}_{tsj} \leq 0, \text{ where } y^{PT} \text{ is a zero or one integer.} \quad (10b)$$

Thus, y^{PR} and y^{PT} are the partial load variables for all s to j combinations where t=1,2,...n.

The i subscript is not carried on the y variable, because the trucks and rail cars are shipped from source s, regardless of where the freight equalization concession says they are in effect shipped from. Therefore, any weight limits are controlled by the path from s to j and not from a freight-equalized point to j.

The third equation of this final set establishes the amount of incremental weight over the minimum weight for which the buyer is charged if his shipment is more than the minimum weight. The equations are

$$(y^{R}_{tsj} + y^{PR}_{tsj})\ CMW^{R}_{tsij} + ISW^{R}_{tsj} - MW^{R}_{tsij}(y^{R}_{tsj} + y^{FR}_{tsj}) = 0\ , \qquad (11a)$$

$$(y^{T}_{tsj} + y^{PT}_{tsj})\ CMW^{T}_{tsij} + ISW^{T}_{tsj} - MW^{T}_{tsij}(y^{T}_{tsj} + y^{FT}_{tsj}) = 0\ , \qquad (11b)$$

for each s,j combination, and t=1,2,...n and ISW^{R} and ISW^{T} are greater than or equal to zero. The incremental weight for each shipment by rail (ISW^{R}) or truck (ISW^{T}) represents the weight not already paid for in the fixed charge shipping function (1b). This incremental weight is the difference between the actual weight shipped from source s to warehouse j during period t, and the carrier's minimum weight requirement (CMW^{R} and CMW^{T}) times the number of trucks or rail cars used. This method of tracking the number of trucks or rail cars is necessary, because while the railroads and truckers break down their tariffs to a unit weight, there is a minimum fee for shipping a rail car or truck, for which the buyer must pay, regardless of the amount shipped in that rail car or truck.

These equations represent a mathematical model, which, when expanded, will give the materials man the opportunity to optimize tubular buying, shipping, and storage. Furthermore, the model ensures tubulars will be purchased in a timely manner and from the widest range of sources, which the materials man can control.

CHAPTER IV

RESULTS AND ANALYSIS

The tubular buying, transporting and storage model developed to this point is represented by generalized equations. These equations will be expanded in this section using a simplified example. The numbers used in this example are current prices as of the second quarter of 1980. The tubular prices used are shown in more detail in Appendix C of this paper. Table I details the example used in the paper.

The model constructed in this paper is designed to be run with a minimum of hard-to-get information. The model is designed to use data already available to the materials section, which the materials section uses to perform the buying, shipping and storage functions. The model merely takes these data and searches for an optimal solution much faster than can be done by hand.

Data acquisition begins with the price lists and other published data. The steel mills which sell tubulars all put out a price list (Appendix C). This price list spells out the price and terms for each kind of tubular. Prices for jobbers and local stores are obtained either by calling for a quotation or by price lists published by these supply sources. In general, tubular prices for non-mill sources can be predicted by the type of source and the market supply-demand conditions. In conversations with the Phillips materials group, the jobber and local store prices vary as follows:

1) The mill price may go up during a tubular shortage and mills will not freight equalize with other mills;

2) Tubular storage and supply yards owned by tubular mills charge the same price as the mill when tubulars are not tight, but will charge 10% more than the mill when tubulars get tight (that is, demand exceeds supply);

3) Jobbers charge the same as the mill when supply exceeds demand, but will charge about 6% more when tubulars get tight. Jobbers make their money from the discount they get from the mill. The mills give jobbers a 6% discount from the listed prices;

4) Local stores sell tubulars at about a 10% premium when the supplies are not tight. As tubular supplies tighten, this premium rises to about 20%.

These are useable guidelines, unless the materials section prefers to get a quotation from the jobbers and local suppliers normally used. These general price adjustments are based on the mill price. The mill price can also change with market conditions. Over the past ten years, market prices have had large fluctuations (over a two or three-year span, prices have doubled and fallen by more than half), but the price trend is upward to keep up with inflation.

Using the data from Table I, function (1a) can be expanded from

$$\sum_k \sum_t \sum_s \sum_i \sum_j C_{kts}(1+E)X_{ktsij}$$

to

$$C_{1,1,1}(1+E)X_{1,1,1,1,1} + C_{1,1,1}(1+E)X_{1,1,1,1,2} + C_{1,1,2}(1+E)X_{1,1,2,2,1} +$$
$$C_{1,1,2}(1+E)X_{1,1,2,2,2} + C_{2,1,1}(1+E)X_{2,1,1,1,1} + C_{2,1,1}(1+E)X_{2,1,1,1,2} +$$

TABLE I

DATA FOR THE EXAMPLE SHOWN IN THIS ANALYSIS

TUBULARS TYPES

- k=1 9-5/8" diameter, J55 steel grade, 40 pounds/foot weight, buttress joint;
- k=2 5" diameter, J55 steel grade, 15 pounds/foot weight, round thread with a long coupling.

TIME -- 2 periods, each equal to one month

SOURCES

- s=1 jobber
- s=2 Lone Star Tubing Mill

LOCATION

- i=1 Houston, Texas
- i=2 LoneStar, Texas

WAREHOUSE LOCATION

- j=1 Odessa, Texas
- j=2 Eldorado, Arkansas

FINAL DESTINATION

- d=1 well close to and supplied by Odessa, Texas to be drilled during time period one;
- d=2 well near and supplied by Eldorado, Arkansas to be drilled during time period two.

TUBULAR PRICES -- assume demand exceeds supply (price per foot)

	Time Period One		Time Period Two	
	9-5/8"	5"	9-5/8"	5"
Mill	17.10	6.38	17.96	6.70
Jobber	18.13	6.76	19.03	7.10

SHIPPING DISTANCE

Mill to Odessa	452 miles	Jobber to Odessa	518 miles
Mill to Eldorado	155 miles	Jobber to Eldorado	378 miles

FIXED STORAGE CHARGE (both warehouses are leased)

Odessa $300 per month
Eldorado $250 per month

TABLE I (CONTINUED)

VARIABLE STORAGE COST

Odessa	\$0.35 per ton per period
Eldorado	\$0.35 per ton per period

HOLDING COST

1% per month of the average value of the tubular, approximated by 1% of the mill price from the closest mill.

INVENTORY LEVEL AVAILABLE FOR TRANSSHIPPING DURING TIME PERIOD ONE

NONE AVAILABLE

TUBULAR REQUIREMENT (TR)

Well d=1	12,000 feet of 5' casing = $TR_{2,1,1}$
	1,500 feet of 9-5/8" casing = $TR_{1,1,1}$
Well d=2	5,000 feet of 5" casing = $TR_{2,2,2}$
	500 feet of 9-5/8" casing = $TR_{1,2,2}$

MILL ALLOCATION IN TONS (MT)

MT_2=110 tons or 220,000 pounds

TUBULAR AVAILABILITY (TS)

Source	Time Period	Tubular Quantity
Jobber (s=1)	t=1	4,000 feet of 5" casing, 400 feet of 9-5/8" casing
	t=2	3,000 feet of 5" casing, 700 feet of 9-5/8" casing
Mill (s=2)	t=1	10,000 feet of 5" casing, 1,400 feet of 9-5/8" casing
	t=2	3,000 feet of 5" casing 0 feet of 9-5/8" casing

PERCENTAGE OF TUBULARS PURCHASED FROM EACH SOURCE (P)

Jobber	44%
Mill	65%

NUMBER OF SOURCES TO BE USED (G) -- 2

TABLE I (CONTINUED)

TRANSPORTATION WEIGHT LIMITATION

MW^R (maximum weight per rail car) = 80,000 pounds
MW^T (maximum weight per truck) = 40,000 pounds

Assume only trucking is available, because the warehouse locations do not have a rail car siding from which to unload.

CMW^T = 30,000 pounds

SHIPPING COST

Use schedules in column 6 in Appendix A.

$$C_{2,1,2}(1+E)X_{2,1,2,2,1} + C_{2,1,2}(1+E)X_{2,1,2,2,2} + C_{1,2,1}(1+E)X_{1,2,1,1,1} +$$
$$C_{1,2,1}(1+E)X_{1,2,1,1,2} + C_{1,2,2}(1+E)X_{1,2,2,2,1} + C_{1,2,2}(1+E)X_{1,2,2,2,2} +$$
$$C_{2,2,1}(1+E)X_{2,2,1,1,1} + C_{2,2,1}(1+E)X_{2,2,1,1,2} + C_{2,2,2}(1+E)X_{2,2,2,2,1} +$$
$$C_{2,2,2}(1+E)X_{2,2,2,2,2} \quad ,$$

and finally to:

$$18.13\ X_{1,1,1,1,1} + 18.13\ X_{1,1,1,1,2} + 17.10\ X_{1,1,2,2,1} + 17.10\ X_{1,1,2,2,2} +$$
$$6.76\ X_{2,1,1,1,1} + 6.76\ X_{2,1,1,1,2} + 6.38\ X_{2,1,2,2,1} + 6.38\ X_{2,1,2,2,2} +$$
$$19.03\ X_{1,2,1,1,1} + 19.03\ X_{1,2,1,1,2} + 17.96\ X_{1,2,2,2,1} + 17.96\ X_{1,2,2,2,2} +$$
$$7.10\ X_{2,2,1,1,1} + 7.10\ X_{2,2,1,1,2} + 6.70\ X_{2,2,2,2,1} + 6.70\ X_{2,2,2,2,2} \ .$$

The shipping cost is a function of fixed and variable costs when shipping is done by truck. When shipping by truck, up to a minimum weight, the shipping cost does not change. Over a certain weight, the added weight costs so many cents per hundred weight to ship. The minimum weight which the buyer is charged is dependent on which rate schedule the trucking company is using. These rates are subject to ICC regulations and are published by the Oil Field Haulers Association, Inc. Appendix A gives a sample calculation and a section of the tariffs.

When shipping by rail, the shipping rate is negotiated between the buyer and the railroad. The buyer first calculates the estimated railroad cost. This is done using a worksheet like the one found on page B-1 in Appendix B. Each item on the worksheet can be estimated using the current Rail Carload Cost Scales, which is published by the ICC (Interstate Commerce Commission) Bureau of Accounts. These publications normally run three years behind, so the costs are escalated using ratios published in industrial publications like Traffic World. With this cost, the buyer looks at both the published rate schedules and his past shipping cost. Using these items, the buyer and the railroad negotiate a rate, and the railroad must get the ICC's approval if the rate is a new one. This approval takes about forty-five days. Presently, Congress is working on legislation which will change the rate rules for the transportation industry. If possible, the railroad will try to set the shipping rates slightly less than any other means of transportation.

The two shipping functions (1b and 1c)

$$\sum_t \sum_s \sum_i \sum_j (CMW^R_{tsij})\, a^R_{tsij}(y^R_{tsj} + y^{PR}_{tsj}) + \sum_t \sum_s \sum_i \sum_j (CMW^T_{tsij})\, a^T_{tsij}(y^T_{tsj} + y^{PT}_{tsj})$$

and

$$\sum_t \sum_s \sum_i \sum_j a^R_{tsij}(ISW^R_{tsj}) + \sum_t \sum_s \sum_i \sum_j a^T_{tsij}(ISW^T_{tsj})$$

can be expanded (assuming no rail transportation, s=i and CMW^T is a constant) to

$$\begin{aligned} CMW^T\, (&a^T_{1,1,1,1}(y^T_{1,1,1} + y^{PT}_{1,1,1}) + a^T_{1,2,2,1}(y^T_{1,2,1} + y^{PT}_{1,2,1}) + \\ &a^T_{1,1,1,2}(y^T_{1,1,2} + y^{PT}_{1,1,2}) + a^T_{1,2,2,2}(y^T_{1,2,2} + y^{PT}_{1,2,2}) + \\ &a^T_{2,1,1,1}(y^T_{2,1,1} + y^{PT}_{2,1,1}) + a^T_{2,2,2,1}(y^T_{2,2,1} + y^{PT}_{2,2,1}) + \\ &a^T_{2,1,1,2}(y^T_{2,1,2} + y^{PT}_{2,1,2}) + a^T_{2,2,2,2}(y^T_{2,2,2} + y^{PT}_{2,2,2})) \end{aligned}$$

and

$$\begin{aligned} &a^T_{1,1,1,1} ISW^T_{1,1,1} + a^T_{1,1,1,2} ISW^T_{1,1,2} + a^T_{1,2,2,1} ISW^T_{1,2,1} + \\ &a^T_{1,2,2,2} ISW^T_{1,2,2} + a^T_{2,1,1,1} ISW^T_{2,1,1} + a^T_{2,1,1,2} ISW^T_{2,1,2} + \\ &a^T_{2,2,2,1} ISW^T_{2,2,1} + a^T_{2,2,2,2} ISW^T_{2,2,2} \quad , \end{aligned}$$

and finally, using data from Table I, to:

$$\begin{aligned} &612(y^T_{1,1,1} + y^{PT}_{1,1,1}) + 567(y^T_{1,2,1} + y^{PT}_{1,2,1}) + 471(y^T_{1,1,2} + y^{PT}_{1,1,2}) \\ &+ 291(y^T_{1,2,2} + y^{PT}_{1,2,2}) + 612(y^T_{2,1,1} + y^{PT}_{2,1,1}) + 567(y^T_{2,2,1} + y^{PT}_{2,2,1}) \\ &+ 471(y^T_{2,1,2} + y^{PT}_{2,1,2}) + 291(y^T_{2,2,2} + y^{PT}_{2,2,2}) \text{ and} \end{aligned}$$

$$\begin{aligned} &(.0204)ISW^T_{1,1,1} + (.0157)ISW^T_{1,1,2} + (.0189)ISW^T_{1,2,1} + (.0097)ISW^T_{1,2,2} \\ &+ (.0204)ISW^T_{2,1,1} + (.0157)ISW^T_{2,1,2} + (.0189)ISW^T_{2,2,1} + (.0097)ISW^T_{2,2,2}. \end{aligned}$$

The third cost function is the cost to store tubulars in the leased or company warehouse. These rates are set by the warehouse owner, generally a trucking company, if the warehouse space is leased, or the rates are calculated from accounting data if the warehouse is company-owned. Company-owned warehouses may charge by the unit weight, by the gross value of the tubulars, or even by the square feet of warehouse space used. This charge is added to the tubulars and charged to the well as part of the cost of the tubulars used in the well. Loading and unloading charges at a leased warehouse are not considered in this example. Since these charges are normally on a weight basis, they can be handled in the transportation function. The storage function

$$\sum_j F_j y_j^F + \sum_j b_{tj} \left[\sum_k \sum_{t=1}^{t} \sum_s W_k X_{ktsij} - \sum_k \sum_{t=1}^{t} \sum_d TR_{ktjd} \right] \quad \text{for } t=1,2,\ldots n$$

can be expanded to $F_1 j_1^F + F_2 j_2^F + b_{1,1}(W_1 X_{1,1,1,1,1} + W_1 X_{1,1,2,2,1} + W_2 X_{2,1,1,1,1} + W_2 X_{2,1,2,2,1} - W_1 TR_{1,1,1,1} - W_2 TR_{2,1,1,1}) + b_{1,2}(W_1 X_{1,1,1,1,2} + W_1 X_{1,1,2,2,2} + W_2 X_{2,1,1,1,2} + W_2 X_{2,1,2,2,2} - W_1 TR_{1,1,2,2} - W_2 TR_{2,1,2,2} + b_{2,1}(W_1 X_{1,1,1,1,1} + W_1 X_{1,1,2,2,1} + W_2 X_{2,1,1,1,1} + W_2 X_{2,1,2,2,1} + W_1 X_{1,2,1,1,1} + W_1 X_{1,2,2,2,1} + W_2 X_{2,2,1,1,1} + W_2 X_{2,2,2,2,1} - W_1 TR_{1,1,1,1,} - W_2 TR_{2,1,1,1} - W_1 TR_{1,2,1,1} - W_2 TR_{2,2,1,1}) + b_{2,2}(W_1 X_{1,1,1,1,2} + W_1 X_{1,1,2,2,2} + W_2 X_{2,1,1,1,2} + W_2 X_{2,1,2,2,2} + W_1 X_{1,2,1,1,2} + W_1 X_{1,2,2,2,2} + W_2 X_{2,2,1,1,2} + W_2 X_{2,2,2,2,2} - W_1 TR_{1,1,2,2} - W_2 TR_{2,1,2,2} - W_1 TR_{1,2,2,2} - W_2 TR_{2,2,2,2})$,

and finally, using the data in Table I, to

$300\ y_1^F + 250\ y_2^F + 0.000175(40X_{1,1,1,1,1} + 40X_{1,1,2,2,1} + 15X_{2,1,1,1,1} + 15X_{2,1,2,2,1} - 40(1500) - 15(12000)) + 0.000175(40X_{1,1,1,1,2} + 40X_{1,1,2,2,2} + 15X_{2,1,1,1,2} + 15X_{2,1,2,2,2} - 0 - 0) + 0.000175(40X_{1,1,1,1,1} + 40X_{1,1,2,2,1} \ldots + 15X_{2,1,2,2,1} - 40(1500) - 15(12000) - 0 - 0) + 0.000175(40X_{1,1,1,1,2} \cdots + 15X_{2,2,2,2,2} - 0 - 0 - 40(500) - 15(5000))$.

The final cost function is that of the opportunity cost foregone by investing in tubulars. This function is similar to storage cost, except no money really changes hands. Only if the tubulars were bought with borrowed money would the hold cost be clearly tied to a cash outlay. Normally, internal funds are used for tubular purchases, thus the foregone investment opportunity is not realized by many people. While oil companies are not in the business of investing in inventory, at times, the hold cost may reduce the total materials cost, due to a price increase which exceeds the cost of money. Hold cost in this model will be one percent per month of the sales value of tubulars. This is only one of the many ways that opportunity costs could be handled.

The hold cost function (1e)

$$\sum_k \sum_j IS_{ktj}\left(\sum_{t=1}^{t} \sum_s X_{ktsij} - \sum_{t=1}^{t} \sum_d TR_{ktjd}\right) \text{ for } t=1,2,\ldots n$$

expands to: $IS_{1,1,1}(X_{1,1,1,1,1} + X_{1,1,2,2,1} - TR_{1,1,1,1}) + IS_{1,1,2}(X_{1,1,1,1,2} + X_{1,1,2,2,2} - TR_{1,1,2,2}) + IS_{2,1,1}(X_{2,1,1,1,1} + X_{2,1,2,2,1} - TR_{2,1,1,1}) + IS_{2,1,2}(X_{2,1,1,1,2} + X_{2,1,2,2,2} - TR_{2,1,2,2}) + IS_{1,2,1}(X_{1,1,1,1,1} + X_{1,1,2,2,1} + X_{1,2,1,1,1} + X_{1,2,2,2,1} - TR_{1,1,1,1} - TR_{1,2,1,1}) + IS_{1,2,2}(\ldots) + IS_{2,2,1}(\ldots) + IS_{2,2,2}(X_{2,1,1,1,2} + X_{2,1,2,2,2} + X_{2,2,1,1,2} + X_{2,2,2,2,2} - TR_{2,1,2,2} - TR_{2,2,2,2})$. This expanded version can be easily substituted with numbers for IS and TR.

Each of the warehouse locations must be kept separate, because if a function of sales value of the tubulars is used for inventory cost, the sales value may be different from location to location. This is particularly true in an international market, because import tariffs and transportation over long distances can substantially reduce the value of tubulars if they must be sold in a distant location.

The first model constraint is a combination inventory equation and demand equation. The equation

$$\sum_{t=1}^{t} \sum_{s} X_{ktsij} - \sum_{t=1}^{t} \sum_{d} TR_{ktjd} \geq 0 \text{ for } k=1,2,\ldots n;\ t=1,2,\ldots n;\ j=1,2,\ldots n$$

expands to

$$X_{1,1,1,1,1} + X_{1,1,2,2,1} - TR_{1,1,1,1} \geq 0 \qquad k=1,\ t=1,\ j=1$$

$$X_{2,1,1,1,1} + X_{2,1,2,2,1} - TR_{21,1,1} \geq 0 \qquad k=2,\ t=1,\ j=1$$

$$X_{1,1,1,1,2} + X_{1,1,2,2,2} - TR_{1,1,2,2} \geq 0 \qquad k=1,\ t=1,\ j=2$$

$$X_{2,1,1,1,2} + X_{2,1,2,2,2} - TR_{2,1,2,2} \geq 0 \qquad k=2,\ t=1,\ j=2$$

$$X_{1,1,1,1,1} + X_{1,1,2,2,1} + X_{1,2,1,1,1} + X_{1,2,2,2,1} - TR_{1,1,1,1} - TR_{1,2,1,1} \geq 0$$
$$k=1,\ t=2,\ j=1$$

$$X_{2,1,1,1,1} + X_{2,1,2,2,1} + X_{2,2,1,1,1} + X_{2,2,2,2,1} - TR_{2,1,1,1} - TR_{2,2,1,1} \geq 0$$
$$k=2,\ t=2,\ j=1$$

$$X_{1,1,1,1,2} + X_{1,1,2,2,2} + X_{1,2,1,1,2} + X_{1,2,2,2,2} - TR_{1,1,2,2} - TR_{1,2,2,2} \geq 0$$
$$k=1,\ t=2,\ j=2$$

$$X_{2,1,1,1,2} + X_{2,1,2,2,2} + X_{2,2,1,1,2} + X_{2,2,2,2,2} - TR_{2,1,2,2} - TR_{2,2,2,2} \geq 0$$
$$k=2,\ t=2,\ j=2.$$

Numbers from Table I are then substituted for the above eight equations. For k=1, t=2, j=2, the equation for this example becomes

$$X_{1,1,1,1,2} + X_{1,1,2,2,2} + X_{1,2,1,1,2} + X_{1,2,2,2,2} - 0 - 500 \geq 0.$$

These equations ensure the tubulars required at the well or for day-to-day well workovers will be available. When TR is a well requirement, it will appear only once in the model, that is, a drilling well requires casing only once, when it is drilled. However, because wells can take several months to drill, not all casing may be brought to the well in the same time period. Thus, for a given well, not all the tubulars may be bought in the same time period. The value of TR, the tubular requirement, can have a number of sources. These sources depend on whether the requirement is for a new well or a warehouse location. For the warehouse location, the values are typically whatever the local office can get the company to buy. This results in unnecessary surplus. A better way might be to analyze past requirements on a per well basis, in order to determine a time series relationship which would predict warehouse inventory needs based on the number of active wells and any other relevant parameters.

For the well needs, materials people get requirements from field offices from one to twelve months in advance. These estimates are based on the proposed wells to be drilled and the tubular requirements for each well. Due to the uncertainty of the drilling schedule, it changes constantly. Using the requested requirements, the materials section estimates the buying needs by tempering the requirement with past experience. Past experience may tell the materials man that there are not enough drilling rigs in the area to drill the number of wells the field office has in mind, or, experience may cause the materials man to ask if certain, more readily available types of tubulars might do the job just as well as the proposed tubulars for a given well. The field office and the materials man are somewhat at odds with each other. The field office wants maximum flexibility in its drilling schedule, so it asks for all the tubulars it might need. The materials man is trying to keep inventories at a minimum, while supplying the field requirement, because the cost of a drilling rig waiting on tubulars to be delivered will probably exceed the value of the tubulars.

The next two equations represent the quantity of supplies available to the buyer. These quantities are in terms of total weight purchased and each kind of tubular purchased. In dealing with a mill, a negotiation takes place. The buyer is told his weight limit for the period and the mill's rolling schedule by the mill. From here, the buyer puts in an order, and then the mill responds with the amount they will supply. In Table I, the mill's rolling schedule, total weight allocation, and the quantity the jobber and mill are willing to sell the buyer are given. In reality, the quantity may not be available until the order is placed. Therefore, the model can be run with some assumed number and then revised as the mill and jobber respond to an order. The equations $\sum_j X_{ktsij} - TS_{kts} \leq 0$ for k=1,2,...n, t=1,2,...n, and s=1,2,...n and $\sum_k \sum_t \sum_j W_k X_{ktsij} - MT_s \leq 0$ for s=1,2,...n expand to:

$X_{1,1,1,1,1} + X_{1,1,1,1,2} - TS_{1,1,1} \leq 0$ k=1, t=1, s=1

$X_{2,1,1,1,1} + X_{2,1,1,1,2} - TS_{2,1,1} \leq 0$ k=2, t=1, s=1

$X_{1,1,2,2,1} + X_{1,1,2,2,2} - TS_{1,1,2} \leq 0$ k=1, t=1, s=2

$X_{2,1,2,2,1} + X_{2,1,2,2,2} - TS_{2,1,2} \leq 0$ k=2, t=1, s=2

$X_{1,2,1,1,1} + X_{1,2,1,1,2} - TS_{1,2,1} \leq 0$ k=1, t=2, s=1

$X_{2,2,1,1,1} + X_{2,2,1,1,2} - TS_{2,2,1} \leq 0$ k=2, t=2, s=1

$X_{1,2,2,2,1} + X_{1,2,2,2,2} - TS_{1,2,2} \leq 0$ k=1, t=2, s=2

$X_{2,2,2,2,1} + X_{2,2,2,2,2} - TS_{2,2,2} \leq 0$ k=2, t=2, s=2

and $W_1X_{1,1,2,2,1} + W_1X_{1,1,2,2,2} + W_2X_{2,1,2,2,1} + W_2X_{2,1,2,2,2} + W_1X_{1,2,2,2,1} + W_1X_{1,2,2,2,2} + W_2X_{2,2,2,2,1} + W_2X_{2,2,2,2,2} - MT_2 \leq 0$. MT_1 does not exist because the jobber sells tubulars as items and is not concerned about total weight. Numbers for TS and MT for these equations can be inserted from Table I.

The model uses three equations to regulate how much is bought from each supply source. These equations,

$$\frac{\sum_k \sum_t \sum_j W_k X_{ktsij}}{\sum_k \sum_t \sum_s \sum_j W_k X_{ktsij}} \leq P_s \text{ for } s=1,2,\ldots n$$

$$\sum_k \sum_t X_{ktsij} - y_s^S M \leq 0 \quad \text{for } s=1,2,\ldots n$$
$$\sum y_s^S \geq G ,$$

ensure that enough mills (and, to a lesser extent, jobbers) are ordered from, so that as tubulars become difficult to obtain, the buyer has a working arrangement with the mills. If any inventory is carried into this model, it is, as was stated before, treated as a supply point with goods available in the first time period. In these equations, P for this kind of supply point can be set at some high value like 1.00, and G can be increased by the number of these pseudo supply points.

The values for P and G are set by the materials section of the buyer. P keeps any one supplier from gaining too much of the total order, while G ensures that a number of sources will be used. These equations are expanded into the following:

$$W_1X_{1,1,1,1,1} + W_2X_{2,1,1,1,1} + W_1X_{1,1,1,1,2} + W_2X_{2,1,1,1,2} + W_1X_{1,2,1,1,1} + W_2X_{2,2,1,1,1} + W_1X_{1,2,1,1,2} + W_2X_{2,2,1,1,2} - P_1\big[W_1X_{1,1,1,1,1} + W_2X_{2,1,1,1,1} \ldots + W_2X_{2,2,1,1,2} + W_1X_{1,1,2,2,1} + W_2X_{2,1,2,2,1} \ldots W_2X_{2,2,2,2,2}\big] \leq 0 \qquad s=1$$

$$W_1X_{1,1,2,2,1} + W_2X_{2,1,2,2,1} + \ldots + W_2X_{2,2,2,2,2} - P_2\big[W_1X_{1,1,1,1,1} + \ldots W_2X_{2,2,1,1,2} + W_1X_{1,1,2,2,1} + \ldots + W_2X_{2,2,2,2,2}\big] \leq 0 \qquad s=2$$

and $X_{1,1,1,1,1} + X_{2,1,1,1,1} + X_{1,2,1,1,1} + X_{2,2,1,1,1} + X_{1,1,1,1,2} + X_{2,1,1,1,2} + X_{1,2,1,1,2} + X_{2,2,1,1,2} - y_1^S M \leq 0 \qquad s=1$

$$X_{1,1,2,2,1} + X_{2,1,2,2,1} + X_{1,2,2,2,1} + X_{2,2,2,2,1} + X_{1,1,2,2,2} + X_{2,1,2,2,2} + X_{1,2,2,2,2} + X_{2,2,2,2,2} - y_2^S M \leq 0 \qquad s=2$$

$$y_1^S + y_2^S \geq G.$$

In this example from Table I, G would be 2 and M should be around 20,000. In a full network model, G could become 20, not counting any warehouse inventory supply points, and M might become 20 million to ensure that the equations do not restrict the tubular purchases from any one source. The equation's purpose is to force the model to buy from more sources. In forcing the model to buy from a source the model would not normally choose, the cost function is not truly minimized. However, this is only true in the short run. In the long run, this may ensure supplies when supplies cannot keep up with demand. The model can be run several times to see what the additional cost is to buy from that last supplier. If this cost is identified, it may be that it would be better not to buy from that last supplier.

The equation $\sum_k \sum_t \sum_s X_{ktsij} - y_j^F M \leq 0$ for j=1,2,...n supplies the storage function (1d) with the zero or one integer for the fixed cost part of the function. In this equation, the number of warehouses is not forced to be above a minimum number. If the user of this model intends to use all warehouse locations, or if wells are serviced from a single warehouse, then the fixed cost part of the storage equation and this equation are not needed. The equation expands to:

$$X_{1,1,1,1,1} + X_{2,1,1,1,1} + X_{1,2,1,1,1} + X_{2,2,1,1,1} + X_{1,1,2,2,1} + X_{2,1,2,2,1} + X_{1,2,2,2,1} + X_{2,2,2,2,1} - y_1^F M \leq 0 \qquad j=1$$

$$X_{1,1,1,1,2} + X_{2,1,1,1,2} + X_{1,2,1,1,2} + X_{2,2,1,1,2} + X_{1,1,2,2,2} + X_{2,1,2,2,2} + X_{1,2,2,2,2} + X_{2,2,2,2,2} - y_2^F M \leq 0 \qquad j=2.$$

Again, M must be large enough, so this does not restrict tubular flow into any warehouse location.

The final set of equations to be expanded upon are those which deal with the number of rail cars or trucks to be shipped. In the example used in this section, rail cars were assumed not to be practical, so as to simplify the example. Therefore, equations (9), (10b) and (11b) can be expanded as follows:

$\sum_k W_k X_{ktsij} - MW^T_{tsij}\ (y^T_{tsj} + y^{FT}_{tsj}) = 0$ expands to

$W_1X_{1,1,1,1,1} + W_2X_{2,1,1,1,1} - MW^T_{1,1,1,1}(y^T_{1,1,1} + y^{FT}_{1,1,1}) = 0$, t=1, s=1, j=1

$W_1X_{1,1,2,2,1} + W_2X_{2,1,2,2,1} - MW^T_{1,2,2,1}(y^T_{1,2,1} + y^{FT}_{1,2,1}) = 0$, t=1, s=2, j=1

$W_1X_{1,1,1,1,2} + W_2X_{2,1,1,1,2} - MW^T_{1,1,1,2}(y^T_{1,1,2} + y^{FT}_{1,1,2}) = 0$, t=1, s=1, j=2.

The other five combinations of t, s, and j are similarly written.

$y^{FT}_{tsj} - y^{PT}_{tsj} \leq 0$ expands to: $y^{FT}_{1,1,1} - y^{PT}_{1,1,1} \leq 0$, t=1, s=1, j=1

$y^{FT}_{1,1,2} - y^{PT}_{1,1,2} \leq 0$, t=1, s=1, j=2

$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$

$y^{FT}_{2,2,2} - y^{PT}_{2,2,2} \leq 0$, t=2, s=2, j=2

and $(y^T_{tsj} + y^{PT}_{tsj})\ CMW^T_{tsij} + ISW^T_{tsj} - MW^T_{tsij}(y^T_{tsj} + y^{FT}_{tsj}) = 0$ expands to

$(y^T_{1,1,1} + y^{PT}_{1,1,1})\ CMW^T_{1,1,1,1} + ISW^T_{1,1,1} - MW^T_{1,1,1,1}(y^T_{1,1,1} + y^{FT}_{1,1,1}) = 0$

t=1, s=1, j=1

$(y^T_{1,1,2} + y^{PT}_{1,1,2})\ CMW^T_{1,1,1,2} + ISW^T_{1,1,2} - MW^T_{1,1,1,2}(y^T_{1,1,2} + y^{FT}_{1,1,2}) = 0$

t=1, s=1, j=2

$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$

$(y^T_{2,2,2} + y^{PT}_{2,2,2})\ CMW^T_{2,2,2,2} + ISW^T_{2,2,2} - MW^T_{2,2,2,2}(y^T_{2,2,2} + y^{FT}_{2,2,2}) = 0$

t=2, s=2, j=2.

When generating the coefficient matrix for these equations, the only specified numbers in these equations are MW and CMW. In Table I, both are constant. The maximum weight (MW^T and MW^R) is a function of several factors. First, state laws allow gross truck weight to be only so much. Thus, the maximum shipping weight is equal to the difference between the state limit and the net weight of the empty truck. Since each truck has a different empty weight, it also has a different pay load. Next, weight laws differ between states; therefore, the truck must be loaded such that it does not exceed the maximum weight limit of any state it travels through. Rail cars are similar to truck, except their loads are restricted by the weights railroad beds can handle. Normally, these weight restrictions for trucks and rail cars are the limiting factor, and not physical limits that the truck or rail car could hold.

The minimum weights are set by the published ICC rate schedule. An example of one of these is in Appendix A. These minimum weights do nothing more than set the minimum total shipping cost for a particular load.

CHAPTER V

SUMMARY AND CONCLUSIONS

The model developed in this paper was done so for oil country tubulars. The model makeup is extremely general and can thus be used for any type of buying, shipping, or storage problem. The model can be run with many of the equations left out, or with parts of the individual equations set to zero. This is particularly true for the cost functions. Thus, because of the model's general nature, while it works for tubulars, it will work for other commodities as well.

Having initially set up the model, the user will find a large number of coefficients are necessary if the model is to approximate a normal tubulars problem for an oil company. The example used to demonstrate the model was kept small to keep the equations from growing unwieldly. Relating this to Phillips Petroleum Company can be done by expanding the sources from 2, in Table I, to 12 mills, 36 jobbers, and at least 50 local stores. Furthermore, Phillips uses tubulars with over fifteen different diameters, with six or more thread and tool joint configurations, three or four different weights, and three or four different grades. These numbers, when multiplied by forty-five warehouse locations, result in a X_{ktsij} matrix of 300 million locations, assuming that i=s (freight is not equalized) and the model time span is fifty-two weekly time periods.

Fortunately, this number can be greatly reduced through the following:

1) Not all mills make all types of tubulars.

2) Instead of weekly time periods for a year, one week time periods could be used for the first three months, two week time periods for the next three months, and finally monthly time periods for the last six months of a year time span.

3) Not all types of tubulars are required at every warehouse location. In addition, the types of tubulars in common use are restricted to about sixty kinds. The remainder are special-order items which are ordered for a specific well and would not be used for other wells.

These three reductions can result in the X matrix size being reduced to about 8,000,000 locations. The matrix, when combined with the other coefficients and integer variables, still results in a large problem.

The model in ordering tubulars actually orders for a total warehouse need, and not for a well. It is only as the model pulls the tubulars out of the warehouse that they are identified by the model. For this reason, the model is of little help in ordering special types of tubulars which can be ordered from only a few suppliers and which will be shipped to a specific well. The choices are so small, the answer is more easily obtained using a manual solution. This is why a normal model would have only sixty types of tubulars in its data base.

The user may wish to eliminate some of the integer and zero-one variables, to help in the model's solution. First, the zero-one variables for fixed warehousing cost can be eliminated if the user assumes that all wells are serviced by a unique warehouse location. Secondly, by changing the equations dealing with the numbers of trucks and rail cars shipped, the zero-one variable associated with these equations and the transportation cost function could be eliminated. The model could be changed to a continuous cost function. This would require that the weight constraint equations for a truck or rail car have both a minimum and a maximum weight specification. Finally, the user could drop out all the shipping weight constraints if he wished to schedule all the shipments. In dropping out all the shipping weight constraint equations, care would have to be taken, so that a particular shipment did not contain only a few pounds of tubulars.

The model described in this report would be very well suited for a front end and tail end processor program. These programs would be used to calculate coefficients and put the output from the model into a useable form. A front end processor would allow the user to make small changes, then rerun the model with a minimum of effort. To start with, prices for tubulars are often raised as a percent of the existing price, that is, all prices may rise (or fall) by a specified percent. The front end processor could have the option to raise all prices by a percent factor. Shipping and storage costs in the past have also risen by a percent. Thus, the percent rise could be entered into the processor, and the program would calculate a whole new set of coefficients. The front end processor could be used to calculate the coefficients in either a tight market or a soft market (supply exceeds demand). By doing regression analysis on past pricing, these regression coefficients could be entered into the front end program to inflate the model coefficients over time. Freight equalization can be easily taken care of, because for trucks, freight rates are based on distance. For rail service, the computer could either calculate the estimated rail cost using the form in Appendix B or it could analyze the company's recent rail shipments for a suitable rate.

The tail end processor could serve several functions. First, it would output data in a highly useable format. Next, it could indicate warehouse location and suppliers not being utilized so the materials man could see if these locations could be eliminated. The processor could also indicate inventory at each time period. Finally, the tail end processor could set up an initial solution case for the front end processor to load, when the model is next run.

To implement the model will require a computer code capable of handling large network models, as well as integer variables. Existing codes which can solve this problem would most likely use a simplex algorithm with a branch and bound technique to solve for the integer variables. New codes which build on these and other techniques could be specially written for this model to help minimize the computer time necessary to solve this model. The model, while built for tubulars, can be used for many different types of commodities. In addition, the model through appropriate output can be used for cash management. The model is built such that it can handle time. The company could use the time capability to create the capital budget for tubulars. In addition, if the company has certain months when cash may not be available, a constraint could be added to the model, which would restrict buying in those months. The model can be changed to handle lease versus own decisions for new and existing warehouse locations. The model could also be used to help make warehouse geographic location decisions.

The model was designed with the idea that all data used in the model were already available. In developing the model, the author recognized that the model could be used as a forecasting tool for prices, inventories, and costs, if the model were tied to a front end and tail end processor which would allow regression analysis of past information. This analysis would come from a data base of past buying, shipping, and storage movements. Heuristics could also play a part in this forecasting, since people like to feel their ideas are being used. In the extreme, the model could be used to speculate in the tubular market. Here again, the holding costs would come into play. Not only would these holding costs be trying to keep tubular inventories at a minimum, because the cost function is a minimization function, but the holding cost function would also penalize the speculator by showing his total cost, including that of interest on the money tied up in inventory.

The next step in the use of this model is for the model to be run. This will verify that the model is indeed robust and will actually work. In running the model, the user may find areas of deficiency or an area which, if changed, would result in a model which would be more efficient to solve. Only through use can the model's correctness be verified. In addition, the real value of the model is not on paper, but in actual use. The model was written to assist the materials section to buy, ship, and store tubulars such that the costs are kept to a minimum. This saves the company money, the materials section man hours, and helps to ensure that the tubulars are delivered on time to the well or warehouse location.

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APPENDIX A

DISTANCE COMMODITY RATES

FOR TRUCKING

Distance commodity rates tables for truck hauling are used in the following manner:

1) Select the proper column for what is being shipped.

Column 1 -- truck load over 7,000 pounds hauling pipe or machinery
Column 2 -- truck load over 14,000 pounds hauling machinery
Column 3 -- truck load over 20,000 pounds hauling machinery
Column 4 -- truck load over 14,000 pounds hauling pipe
Column 5 -- truck load over 20,000 pounds hauling pipe
Column 6 -- truck load over 30,000 pounds hauling pipe

2) Select the distance between the shipping and receiving points in the proper column. This represents the cents per hundred pounds to ship over the specified distance. If the load weighs less than the weight listed in the column, then the column weight is used as the shipping weight. If the shipping weight is greater than the column weight, then the shipping weight is used. The freight cost is the rate given in the proper column times the weight (either shipping or column).

For example, assume 36,000 pounds of pipe was to be shipped 405 miles. The rate per hundred pounds is found in Column 6 at a distance of 410 miles. The rate is 166 cents per hundred weight. If the load weighs under 30,000 pounds, the shipping cost is figured on 30,000 pounds. Thus, 30,000 pounds/100 pounds X \$1.66 = \$498 and represents a fixed cost. Any weight over 30,000 pounds, up to state highway weight limits, represents a variable cost. 6,000 pounds/100 X \$1.66 = \$99.60. The total shipping cost is \$597.60.

Section 3 DISTANCE COMMODITY RATES

ITEM NO. 920-A

TABLE OF DISTANCE RATES IN CENTS PER 100 POUNDS ♦
(All Commodities)
For Application See Items 850 and 890

DISTANCE IN MILES	COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4	COLUMN 5	COLUMN 6
10	82	51	43	49	37	34
20	87	58	50	54	43	40
30	96	64	57	60	48	48
40	99	74	64	64	51	51
50	105	84	69	73	56	56
60	122	96	78	82	61	61
70	126	103	85	90	71	71
80	135	107	90	96	78	74
90	148	118	96	102	82	79
100	150	126	101	104	85	82
110	158	134	104	105	90	84
120	171	145	111	114	97	85
130	184	150	120	123	102	87
140	190	155	126	128	105	88
150	201	158	130	132	110	95
160	206	164	133	135	114	97
170	219	175	135	145	120	99
180	223	180	141	148	126	102
190	234	186	148	151	128	104
200	241	190	150	155	132	105
210	250	191	155	156	134	110
220	258	194	157	158	135	114
230	268	205	161	162	139	115
240	282	213	164	174	141	118
250	286	219	170	175	145	123
260	290	220	180	180	149	128
270	296	224	184	185	150	130
280	309	230	185	186	155	132
290	310	237	189	189	157	133
300	318	248	190	192	161	135
310	332	254	204	204	166	142
320	335	265	205	207	171	145
330	341	269	206	215	176	148
340	346	272	207	216	183	149
350	365	277	213	218	184	151
360	367	280	220	226	186	155
370	376	290	222	228	189	156
380	383	296	226	237	190	157
390	398	300	228	241	192	158
400	400	308	230	246	194	161
410	409	309	234	251	204	166
420	421	321	237	254	205	170
430	427	326	248	265	206	174
440	436	330	251	268	207	176
450	444	333	254	271	213	184

(Continued)

For explanation of abbreviations and characters see Item 1300 and last page hereof.

Section 3 DISTANCE COMMODITY RATES

ITEM NO. 920-A Continued

TABLE OF DISTANCE RATES IN CENTS PER 100 POUNDS♦
(All Commodities)
For Application See Items 850 and 890.

DISTANCE IN MILES	COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4	COLUMN 5	COLUMN 6
460	453	341	257	277	222	189
470	463	350	258	280	226	190
480	470	354	259	282	228	191
490	484	359	265	284	230	192
500	486	366	271	292	233	194
510	494	381	283	301	248	201
520	509	392	286	306	253	204
530	516	395	287	309	254	205
540	522	399	289	321	255	206
550	527	401	292	324	256	207
560	536	420	302	332	258	210
570	549	422	303	333	259	215
580	557	428	309	337	265	216
590	564	434	310	341	271	219
600	575	443	317	346	272	220
610	580	444	324	357	282	222
620	586	449	330	359	286	226
630	595	453	333	366	289	228
640	610	466	337	367	292	230
650	614	470	341	371	300	233
660	620	471	344	379	302	234
670	636	476	348	381	309	237
680	642	484	350	392	317	242
690	652	491	354	394	321	250
700	657	497	356	395	330	256
710	671	500	361	399	332	259
720	679	503	366	400	335	270
730	684	511	371	405	341	277
740	690	519	378	412	344	283
750	706	523	388	418	348	290
760	713	524	394	421	350	296
770	720	529	395	422	356	298
780	729	541	399	428	361	301
790	737	546	401	433	366	309
800	746	549	404	434	371	315
810	748	551	407	443	373	317
820	750	554	412	444	382	321
830	752	556	413	449	390	324
840	754	558	418	452	395	332
850	763	561	420	457	397	333
860	772	562	421	466	399	335
870	784	564	430	468	401	340
880	788	577	432	471	412	344
890	796	579	437	473	418	348
900	804	590	438	476	420	350

(Continued)

For explanation of abbreviations and characters see Item 1300 and last page hereof.

Section 3 DISTANCE COMMODITY RATES

ITEM NO. 920-A Continued

TABLE OF DISTANCE RATES IN CENTS PER 100 POUNDS♦
(All Commodities)
For Application See Items 850 and 890.

DISTANCE IN MILES	COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4	COLUMN 5	COLUMN 6
910	814	591	443	484	425	356
920	820	593	452	488	428	359
930	830	599	456	494	434	365
940	838	603	458	497	436	366
950	848	607	463	502	443	372
960	854	615	469	503	445	376
970	864	618	471	506	451	381
980	872	619	476	508	453	382
990	878	626	478	509	454	388
1000	883	629	479	510	456	393
1010	887	633	483	511	457	395
1020	891	636	485	516	459	398
1030	894	639	489	517	463	400
1040	898	642	496	522	468	404
1050	901	649	503	526	471	408
1060	909	665	511	536	478	412
1070	912	670	520	549	486	417
1080	924	673	525	554	493	420
1090	931	685	530	558	499	421
1100	936	691	534	561	501	425
1110	948	702	541	564	508	426
1120	957	711	543	575	511	433
1130	970	716	549	580	519	435
1140	974	720	556	583	523	443
1150	983	725	557	591	524	445
1160	988	730	566	593	526	448
1170	1002	738	567	601	535	450
1180	1006	748	571	605	538	452
1190	1019	752	575	612	539	456
1200	1022	754	577	613	546	463
1210	1033	757	588	617	547	468
1220	1041	764	591	619	549	469
1230	1046	769	594	620	552	471
1240	1062	773	599	629	554	474
1250	1065	781	600	631	557	478
1260	1071	783	603	638	560	483
1270	1081	788	607	645	562	486
1280	1090	799	610	647	566	493
1290	1093	802	613	648	573	499
1300	1101	808	615	653	574	500
1310	1116	816	633	661	583	502
1320	1123	829	634	664	586	506
1330	1126	833	636	674	591	508
1340	1129	835	638	679	592	510
1350	1148	844	641	681	593	516

(Continued)

Section 3 DISTANCE COMMODITY RATES

ITEM NO. 920-A Continued

TABLE OF DISTANCE RATES IN CENTS PER 100 POUNDS♦
(All Commodities)
For Application See Items 850 and 890

DISTANCE IN MILES	COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4	COLUMN 5	COLUMN 6
1360	1151	846	650	687	597	521
1370	1156	854	652	688	600	523
1380	1168	857	654	697	605	524
1390	1177	860	657	702	608	526
1400	1185	864	658	706	610	527
1410	1191	870	661	708	614	536
1420	1199	883	666	711	617	539
1430	1210	886	669	723	618	545
1440	1215	889	672	724	619	547
1450	1222	894	673	727	621	552
1460	1233	899	684	736	635	556
1470	1241	909	685	737	638	557
1480	1245	915	686	739	640	558
1490	1259	917	687	747	642	560
1500	1262	922	699	749	645	562
1510	1267	942	705	759	657	566
1520	1286	945	706	770	659	567
1530	1291	948	708	771	661	573
1540	1296	954	711	777	662	574
1550	1302	959	714	779	664	575
1560	1308	974	725	787	670	576
1570	1320	977	727	788	672	580
1580	1324	981	730	792	674	582
1590	1340	984	731	795	681	586
1600	1346	997	737	798	684	588
1610	1354	1000	748	812	687	591
1620	1359	1003	750	818	692	592
1630	1362	1009	752	824	702	593
1640	1374	1015	754	825	705	595
1650	1383	1020	756	828	710	597
1660	1388	1022	763	833	716	601
1670	1404	1029	765	836	721	607
1680	1407	1034	769	841	724	610
1690	1415	1041	773	843	726	614
1700	1424	1045	775	846	735	619
1710	1435	1047	781	854	736	626
1720	1440	1050	783	856	739	631
1730	1448	1063	789	860	746	640
1740	1456	1066	796	869	749	647
1750	1463	1071	804	870	753	652
1760	1472	1073	807	873	758	657
1770	1477	1076	808	877	770	659
1780	1489	1086	813	881	773	661
1790	1496	1090	818	883	775	664
1800	1507	1098	821	884	778	670

(Continued)

Section 3 DISTANCE COMMODITY RATES

ITEM NO. 920-A Concluded

TABLE OF DISTANCE RATES IN CENTS PER 100 POUNDS♦
(All Commodities)
For Application See Items 850 and 890.

DISTANCE IN MILES	COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4	COLUMN 5	COLUMN 6
1810	1512	1099	829	894	779	674
1820	1520	1103	833	896	787	678
1830	1525	1111	838	902	795	681
1840	1536	1115	841	908	798	684
1850	1541	1117	847	909	799	686
1860	1548	1123	848	914	805	688
1870	1561	1129	854	916	807	692
1880	1566	1140	856	924	818	702
1890	1572	1141	858	925	823	704
1900	1578	1143	864	926	824	706
1910	1591	1146	870	934	829	708
1920	1600	1150	873	939	832	711
1930	1606	1155	881	943	837	718
1940	1614	1168	883	944	843	720
1950	1622	1170	886	950	847	722
1960	1627	1173	893	953	848	723
1970	1642	1177	896	956	856	726
1980	1646	1180	899	968	859	729
1990	1650	1191	904	970	863	733
2000	1666	1195	912	971	867	736

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APPENDIX B

WORKSHEET FOR FIGURING RAIL

FREIGHT RATES

DISTRICT OR REGION

RAIL FORM A TABLE 3 COSTS FOR ICC

	(1)		(2)	(3)	(4)	(5)
Problem No. ______		FROM AND TO:				
		COMMODITY:				
Date: ______		TYPE CAR AND TRAIN:				

OUT OF POCKET COSTS

LINE-HAUL COSTS

			(3)	(4)	(5)
1. Per GTM (Average Train . ____ ¢) (Way Train . ____) (Thru Train . ____) times:	____ Tons= (Tare Wt.)		. ¢	____ Tons= (Tare Wt.)	. ¢
2. (#) Per Loaded Car Mile: ____ ¢ . .			.	. . . . . .	.
3. Total Items 1 and 2			. ¢	. . . . .	. ¢
4. Multiply Item 3 by: (1 plus Mty Return Ratio) = ____ =			.	____	.
5. Item 4 divided by: . . . . . . ____ Cwt. =			.	____ Cwt. =	.
6. Per Cwt. Mi. (Average Train . ____ ¢) (Way Train . ____) (Thru Train . ____)			.	. . . . . .	.
7. Total Items 5 and 6			. ¢	. . . . .	. ¢
8. Item 7 times: . . . . . . ____ Mi. =			.	____ Mi. =	.
9. Interchanged $ ____ . ____ Divided by	____ Cwt. =		.	____ Cwt. =	.
10. Inter-Intra Train Switching $ ____ . ____ Divided by	____ Cwt. =		.	____ Cwt. =	.
11. Total Line-Haul Costs per Cwt.			.	. . . . . .	.

TERMINAL COSTS

		(3)	(4)	(5)
12. Per Car Load ____ . ____ ¢ Divided by	____ Cwt. =	.	____ Cwt. =	.
13. Per Cwt. ____ . ____ ¢		.	. . . . .	.
14. Loss and Damage Factor		.	. . . . .	.
15. Total Terminal Costs (Items 12 plus 13 plus 14)		. ¢	. . . . .	. ¢
16. TOTAL O-o-P COSTS PER CWT.-(Items 11 plus 15)		.	. . . . . .	. ¢
17. TOTAL O-o-P COSTS PER CAR-Item 16 times:	____ Cwt. =	$.	____ Cwt. =	$.

CONSTANT COSTS

LINE-HAUL AND TERMINAL COSTS

		(3)	(4)	(5)
18. Line-Haul Costs Per Cwt. Mile: . ____ ¢ times:	____ Mi. =	.	____ Mi. =	.
19. Interchanged . ____ ¢ per cwt.	=	.	. . . . =	.
20. Inter-Intra Train Switching . ____ ¢ per cwt.	=	.	. . . . =	.
21. Terminal Costs . ____ ¢ per cwt.	=	.	. . . . =	.
22. Total Constant Costs (Items 18 thru 21)		. ¢	. . . .	. ¢
23. TOTAL FULLY DISTR. COSTS PER CWT. (Items 16 plus 22)		. ¢	. . . . =	. ¢
24. TOTAL FULLY DISTR. COSTS PER CAR, Item 22 times ____ Cwt. =		$.	____ Cwt. =	$.

(#) For tank cars 5.5¢ Mileage Allowance is included.

APPENDIX C

PRICE LIST FOR TUBULARS

L O N E S T A R S T E E L C O M P A N Y

OIL COUNTRY TUBULAR GOODS
PRICE LIST EFFECTIVE JUNE 01, 1980

PRICES DOLLARS PER 100 FEET - F.O.B. MILL, LONE STAR, TEXAS

SIZE O.D. INCHES	WEIGHT LBS. PER FT.	WALL INCHES	GRADE	T&C END FINISH	MFG. SPECS.	MILL PRICE
2.375	4.60	.190	H-40	NUE	API	245.37
			J-55	NUE	API	251.60
			C-75	NUE	API	383.73
			N-80	NUE	API	338.86
2.375	4.70	.190	H-40	EUE	API	259.01
			J-55	EUE	API	265.59
			C-75	EUE	API	405.11
			N-80	EUE	API	357.72
2.875	6.40	.217	H-40	NUE	API	313.08
			J-55	NUE	API	321.03
			C-75	NUE	API	489.48
			N-80	NUE	API	432.27
2.875	6.50	.217	H-40	EUE	API	326.92
			J-55	EUE	API	335.22
			C-75	EUE	API	511.16
			N-80	EUE	API	451.41
3.500	9.20	.254	H-40	NUE	API	445.08
			J-55	NUE	API	456.37
			C-75	NUE	API	695.81
			N-80	NUE	API	614.49
3.500	9.30	.254	H-40	EUE	API	462.78
			J-55	EUE	API	474.53
			C-75	EUE	API	723.57
			N-80	EUE	API	638.99
4.500	9.50	.205	K-55	SHORT	API	411.29
4.500	10.50	.224	K-55	SHORT	API	448.51
			K-55	BUTTRESS	API	503.25
4.500	11.60	.250	K-55	SHORT	API	486.29
			K-55	LONG	API	510.31
			K-55	BUTTRESS	API	545.63
			N-80	LONG	API	654.46
			N-80	BUTTRESS	API	699.87
			L-80	LONG	API	774.58
			L-80	BUTTRESS	API	828.39
			SS-95	LONG	LSS	859.77
			SS-95	BUTTRESS	LSS	919.55
			S-95	LONG	LSS	757.70
			S-95	BUTTRESS	LSS	810.33
			CYS-95	LONG	LSS	832.89
			CYS-95	BUTTRESS	LSS	890.79
			C-95	LONG	API	841.85

PRICE IN EFFECT AT TIME OF SHIPMENT WILL APPLY

L O N E S T A R S T E E L C O M P A N Y

OIL COUNTRY TUBULAR GOODS
PRICE LIST EFFECTIVE JUNE 01, 1980

PRICES DOLLARS PER 100 FEET - F.O.B. MILL, LONE STAR, TEXAS

SIZE O.D. INCHES	WEIGHT LBS. PER FT.	WALL INCHES	GRADE	T&C END FINISH	MFG. SPECS.	MILL PRICE
4.500	11.60	.250	C-95	BUTTRESS	API	900.37
			S-105	LONG	LSS	822.60
			S-105	BUTTRESS	LSS	879.78
4.500	13.50	.290	N-80	LONG	API	761.63
			N-80	BUTTRESS	API	814.47
			L-80	LONG	API	901.42
			L-80	BUTTRESS	API	964.05
			SS-95	LONG	LSS	1002.56
			SS-95	BUTTRESS	LSS	1072.27
			S-95	LONG	LSS	853.81
			S-95	BUTTRESS	LSS	913.10
			CYS-95	LONG	LSS	938.52
			CYS-95	BUTTRESS	LSS	1003.74
			C-95	LONG	API	979.71
			C-95	BUTTRESS	API	1047.82
			S-105	LONG	LSS	898.41
			S-105	BUTTRESS	LSS	960.83
4.500	15.10	.337	SS-95	LONG	LSS	1125.54
			SS-95	BUTTRESS	LSS	1203.80
			S-95	LONG	LSS	976.65
			S-95	BUTTRESS	LSS	1044.49
			CYS-95	LONG	LSS	1073.56
			CYS-95	BUTTRESS	LSS	1148.18
			S-105	LONG	LSS	1006.28
			S-105	BUTTRESS	LSS	1076.19
5.000	11.50	.220	K-55	SHORT	API	480.31
5.000	13.00	.253	K-55	SHORT	API	533.72
			K-55	LONG	API	560.08
			K-55	BUTTRESS	API	598.83
5.000	15.00	.296	K-55	SHORT	API	608.38
			K-55	LONG	API	638.42
			K-55	BUTTRESS	API	682.58
			N-80	LONG	API	818.69
			N-80	BUTTRESS	API	875.47
			L-80	LONG	API	968.91
			L-80	BUTTRESS	API	1036.21
			SS-95	LONG	LSS	1085.15
			SS-95	BUTTRESS	LSS	1160.59
			S-95	LONG	LSS	919.47
			S-95	BUTTRESS	LSS	983.31
			CYS-95	LONG	LSS	1010.67
			CYS-95	BUTTRESS	LSS	1080.89
			C-95	LONG	API	1053.03
			C-95	BUTTRESS	API	1126.22

PRICE IN EFFECT AT TIME OF SHIPMENT WILL APPLY

L O N E S T A R S T E E L C O M P A N Y

OIL COUNTRY TUBULAR GOODS
PRICE LIST EFFECTIVE JUNE 01, 1980

PRICES DOLLARS PER 100 FEET - F.O.B. MILL, LONE STAR, TEXAS

SIZE O.D. NCHES	WEIGHT LBS. PER FT.	WALL INCHES	GRADE	T&C END FINISH	MFG. SPECS.	MILL PRICE
5.000	15.00	.296	S-105	LONG	LSS	966.29
			S-105	BUTTRESS	LSS	1033.41
5.000	18.00	.362	N-80	LONG	API	982.42
			N-80	BUTTRESS	API	1050.56
			L-80	LONG	API	1162.68
			L-80	BUTTRESS	API	1243.44
			SS-95	LONG	LSS	1302.73
			SS-95	BUTTRESS	LSS	1393.29
			S-95	LONG	LSS	1104.36
			S-95	BUTTRESS	LSS	1181.04
			CYS-95	LONG	LSS	1213.90
			CYS-95	BUTTRESS	LSS	1298.24
			C-95	LONG	API	1263.63
			C-95	BUTTRESS	API	1351.45
			S-105	LONG	LSS	1160.91
			S-105	BUTTRESS	LSS	1241.54
5.000	23.20	.478	N-80	LONG	API	1266.20
			N-80	BUTTRESS	API	1354.02
			L-80	LONG	API	1498.53
			L-80	BUTTRESS	API	1602.62
			SS-95	LONG	LSS	1754.13
			SS-95	BUTTRESS	LSS	1876.11
			S-95	LONG	LSS	1521.26
			S-95	BUTTRESS	LSS	1626.94
			CYS-95	LONG	LSS	1672.23
			CYS-95	BUTTRESS	LSS	1788.47
			S-105	LONG	LSS	1599.17
			S-105	BUTTRESS	LSS	1710.30
5.500	14.00	.244	K-55	SHORT	API	570.74
5.500	15.50	.275	K-55	SHORT	API	620.45
			K-55	LONG	API	651.09
			K-55	BUTTRESS	API	696.12
5.500	17.00	.304	K-55	SHORT	API	668.59
			K-55	LONG	API	701.59
			K-55	BUTTRESS	API	750.11
			N-80	LONG	API	899.62
			N-80	BUTTRESS	API	962.00
			L-80	LONG	API	1064.64
			L-80	BUTTRESS	API	1138.57
			SS-95	LONG	LSS	1193.53
			SS-95	BUTTRESS	LSS	1276.48
			S-95	LONG	LSS	1009.76
			S-95	BUTTRESS	LSS	1079.85
			CYS-95	LONG	LSS	1109.89

PRICE IN EFFECT AT TIME OF SHIPMENT WILL APPLY

L O N E S T A R S T E E L C O M P A N Y

OIL COUNTRY TUBULAR GOODS
PRICE LIST EFFECTIVE JUNE 01, 1980

PRICES DOLLARS PER 100 FEET - F.O.B. MILL, LONE STAR, TEXAS

SIZE O.D. INCHES	WEIGHT LBS. PER FT.	WALL INCHES	GRADE	T&C END FINISH	MFG. SPECS.	MILL PRICE
5.500	17.00	.304	CYS-95	BUTTRESS	LSS	1186.99
			C-95	LONG	API	1157.06
			C-95	BUTTRESS	API	1237.46
			S-105	LONG	LSS	1061.26
			S-105	BUTTRESS	LSS	1134.95
5.500	20.00	.361	N-80	LONG	API	1058.38
			N-80	BUTTRESS	API	1131.77
			L-80	LONG	API	1252.53
			L-80	BUTTRESS	API	1339.51
			SS-95	LONG	LSS	1370.58
			SS-95	BUTTRESS	LSS	1465.82
			S-95	LONG	LSS	1174.05
			S-95	BUTTRESS	LSS	1255.53
			CYS-95	LONG	LSS	1290.46
			CYS-95	BUTTRESS	LSS	1380.09
			C-95	LONG	API	1361.25
			C-95	BUTTRESS	API	1455.84
			S-105	LONG	LSS	1232.75
			S-105	BUTTRESS	LSS	1318.34
5.500	23.00	.415	N-80	LONG	API	1217.12
			N-80	BUTTRESS	API	1301.51
			L-80	LONG	API	1440.38
			L-80	BUTTRESS	API	1540.40
			SS-95	LONG	LSS	1625.11
			SS-95	BUTTRESS	LSS	1738.06
			S-95	LONG	LSS	1361.64
			S-95	BUTTRESS	LSS	1456.15
			CYS-95	LONG	LSS	1496.65
			CYS-95	BUTTRESS	LSS	1600.61
			C-95	LONG	API	1565.41
			C-95	BUTTRESS	API	1674.18
			S-105	LONG	LSS	1436.59
			S-105	BUTTRESS	LSS	1536.35
7.000	20.00	.272	H-40	SHORT	API	764.60
			K-55	SHORT	API	783.95
7.000	23.00	.317	K-55	SHORT	API	887.28
			K-55	LONG	API	931.07
			K-55	BUTTRESS	API	995.44
			N-80	LONG	API	1193.80
			N-80	BUTTRESS	API	1276.56
			L-80	LONG	API	1412.75
			L-80	BUTTRESS	API	1510.84
			SS-95	LONG	LSS	1486.68
			SS-95	BUTTRESS	LSS	1589.94
			S-95	LONG	LSS	1323.25

PRICE IN EFFECT AT TIME OF SHIPMENT WILL APPLY

OIL COUNTRY TUBULAR GOODS
PRICE LIST EFFECTIVE JUNE 01, 1980

PRICES DOLLARS PER 100 FEET - F.O.B. MILL, LONE STAR, TEXAS

SIZE O.D. INCHES	WEIGHT LBS. PER FT.	WALL INCHES	GRADE	T&C END FINISH	MFG. SPECS.	MILL PRICE
7.000	23.00	.317	S-95	BUTTRESS	LSS	1415.07
			CYS-95	LONG	LSS	1454.43
			CYS-95	BUTTRESS	LSS	1555.44
			C-95	LONG	API	1535.36
			C-95	BUTTRESS	API	1642.03
7.000	26.00	.362	K-55	SHORT	API	989.03
			K-55	LONG	API	1037.83
			K-55	BUTTRESS	API	1109.57
			N-80	LONG	API	1330.64
			N-80	BUTTRESS	API	1422.87
			L-80	LONG	API	1574.65
			L-80	BUTTRESS	API	1683.97
			SS-95	LONG	LSS	1664.34
			SS-95	BUTTRESS	LSS	1779.93
			S-95	LONG	LSS	1478.94
			S-95	BUTTRESS	LSS	1581.56
			CYS-95	LONG	LSS	1625.53
			CYS-95	BUTTRESS	LSS	1738.41
			C-95	LONG	API	1711.29
			C-95	BUTTRESS	API	1830.17
7.000	29.00	.408	N-80	LONG	API	1484.15
			N-80	BUTTRESS	API	1587.03
			L-80	LONG	API	1756.31
			L-80	BUTTRESS	API	1878.24
			SS-95	LONG	LSS	1835.11
			SS-95	BUTTRESS	LSS	1962.55
			S-95	LONG	LSS	1633.29
			S-95	BUTTRESS	LSS	1746.61
			CYS-95	LONG	LSS	1795.17
			CYS-95	BUTTRESS	LSS	1919.82
			C-95	LONG	API	1908.72
			C-95	BUTTRESS	API	2041.32
			S-105	LONG	LSS	1749.89
			S-105	BUTTRESS	LSS	1871.37
7.000	32.00	.453	N-80	LONG	API	1637.71
			N-80	BUTTRESS	API	1751.23
			L-80	LONG	API	1938.03
			L-80	BUTTRESS	API	2072.57
			SS-95	LONG	LSS	2006.02
			SS-95	BUTTRESS	LSS	2145.32
			S-95	LONG	LSS	1786.01
			S-95	BUTTRESS	LSS	1909.91
			CYS-95	LONG	LSS	1963.01
			CYS-95	BUTTRESS	LSS	2099.30
			C-95	LONG	API	2106.21
			C-95	BUTTRESS	API	2252.52

OIL COUNTRY TUBULAR GOODS
PRICE LIST EFFECTIVE JUNE 01, 1980

PRICES DOLLARS PER 100 FEET - F.O.B. MILL, LONE STAR, TEXAS

SIZE O.D. INCHES	WEIGHT LBS. PER FT.	WALL INCHES	GRADE	T&C END FINISH	MFG. SPECS.	MILL PRICE
7.000	32.00	.453	S-105	LONG	LSS	1933.49
			S-105	BUTTRESS	LSS	2067.71
7.000	35.00	.498	N-80	LONG	API	1791.21
			N-80	BUTTRESS	API	1915.37
			L-80	LONG	API	2119.68
			L-80	BUTTRESS	API	2266.83
			SS-95	LONG	LSS	2176.72
			SS-95	BUTTRESS	LSS	2327.87
			S-95	LONG	LSS	1941.32
			S-95	BUTTRESS	LSS	2075.99
			CYS-95	LONG	LSS	2133.70
			CYS-95	BUTTRESS	LSS	2281.83
			C-95	LONG	API	2303.62
			C-95	BUTTRESS	API	2463.65
			S-105	LONG	LSS	2112.10
			S-105	BUTTRESS	LSS	2258.72
7.000	38.00	.540	N-80	LONG	API	1944.73
			N-80	BUTTRESS	API	2079.53
			L-80	LONG	API	2301.35
			L-80	BUTTRESS	API	2461.11
			SS-95	LONG	LSS	2543.42
			SS-95	BUTTRESS	LSS	2720.13
			S-95	LONG	LSS	2179.89
			S-95	BUTTRESS	LSS	2331.15
			CYS-95	LONG	LSS	2395.98
			CYS-95	BUTTRESS	LSS	2562.37
			C-95	LONG	API	2501.06
			C-95	BUTTRESS	API	2674.80
			S-105	LONG	LSS	2294.59
			S-105	BUTTRESS	LSS	2453.68
7.625	24.00	.300	H-40	SHORT	API	920.16
7.625	26.40	.328	K-55	SHORT	API	1017.84
			K-55	LONG	API	1068.07
			K-55	BUTTRESS	API	1141.91
			N-80	LONG	API	1369.46
			N-80	BUTTRESS	API	1464.40
			L-80	LONG	API	1620.62
			L-80	BUTTRESS	API	1733.14
			SS-95	LONG	LSS	1730.22
			SS-95	BUTTRESS	LSS	1850.41
			S-95	LONG	LSS	1536.07
			S-95	BUTTRESS	LSS	1642.67
			CYS-95	LONG	LSS	1688.36
			CYS-95	BUTTRESS	LSS	1805.62
			C-95	LONG	API	1761.27

PRICE IN EFFECT AT TIME OF SHIPMENT WILL APPLY

L O N E S T A R S T E E L C O M P A N Y

OIL COUNTRY TUBULAR GOODS
PRICE LIST EFFECTIVE JUNE 01, 1980

PRICES DOLLARS PER 100 FEET - F.O.B. MILL, LONE STAR, TEXAS

SIZE O.D. INCHES	WEIGHT LBS. PER FT.	WALL INCHES	GRADE	T&C END FINISH	MFG. SPECS.	MILL PRICE
7.625	26.40	.328	C-95	BUTTRESS	API	1883.63
7.625	29.70	.375	N-80	LONG	API	1540.67
			N-80	BUTTRESS	API	1647.48
			L-80	LONG	API	1823.23
			L-80	BUTTRESS	API	1949.82
			SS-95	LONG	LSS	1964.43
			SS-95	BUTTRESS	LSS	2100.90
			S-95	LONG	LSS	1743.96
			S-95	BUTTRESS	LSS	1865.00
			CYS-95	LONG	LSS	1916.87
			CYS-95	BUTTRESS	LSS	2050.01
			C-95	LONG	API	1981.47
			C-95	BUTTRESS	API	2119.13
7.625	33.70	.430	N-80	LONG	API	1748.14
			N-80	BUTTRESS	API	1869.33
			L-80	LONG	API	2068.75
			L-80	BUTTRESS	API	2212.38
			SS-95	LONG	LSS	2276.19
			SS-95	BUTTRESS	LSS	2434.34
			S-95	LONG	LSS	2017.44
			S-95	BUTTRESS	LSS	2157.48
			CYS-95	LONG	LSS	2217.50
			CYS-95	BUTTRESS	LSS	2371.55
			C-95	LONG	API	2248.30
			C-95	BUTTRESS	API	2404.50
			S-105	LONG	LSS	2153.84
			S-105	BUTTRESS	LSS	2303.43
7.625	39.00	.500	N-80	LONG	API	2023.09
			N-80	BUTTRESS	API	2163.34
			L-80	LONG	API	2394.12
			L-80	BUTTRESS	API	2560.34
			SS-95	LONG	LSS	2812.15
			SS-95	BUTTRESS	LSS	3007.64
			S-95	LONG	LSS	2264.87
			S-95	BUTTRESS	LSS	2422.05
			CYS-95	LONG	LSS	2489.41
			CYS-95	BUTTRESS	LSS	2662.30
			C-95	LONG	API	2601.90
			C-95	BUTTRESS	API	2782.67
			S-105	LONG	LSS	2387.30
			S-105	BUTTRESS	LSS	2553.05
7.625	45.30	.595	SS-95	LONG	LSS	3332.27
			SS-95	BUTTRESS	LSS	3563.94
			S-95	LONG	LSS	2922.94
			S-95	BUTTRESS	LSS	3125.96

PRICE IN EFFECT AT TIME OF SHIPMENT WILL APPLY

LONE STAR STEEL COMPANY

OIL COUNTRY TUBULAR GOODS
PRICE LIST EFFECTIVE JUNE 01, 1980

PRICES DOLLARS PER 100 FEET - F.O.B. MILL, LONE STAR, TEXAS

SIZE O.D. INCHES	WEIGHT LBS. PER FT.	WALL INCHES	GRADE	T&C END FINISH	MFG. SPECS.	MILL PRICE
7.625	45.30	.595	CYS-95	LONG	LSS	3212.97
			CYS-95	BUTTRESS	LSS	3436.29
			S-105	LONG	LSS	3033.99
			S-105	BUTTRESS	LSS	3244.78
7.750	46.10	.595	SS-95	LONG	LSS	3559.59
			SS-95	BUTTRESS	LSS	3807.15
			S-95	LONG	LSS	3122.20
			S-95	BUTTRESS	LSS	3339.14
			CYS-95	LONG	LSS	3432.12
			CYS-95	BUTTRESS	LSS	3670.75
			S-105	LONG	LSS	3240.88
			S-105	BUTTRESS	LSS	3466.13
8.625	24.00	.264	K-55	SHORT	API	955.23
			S-80	SHORT	LSS	1040.05
8.625	28.00	.304	H-40	SHORT	API	1072.55
			S-80	SHORT	LSS	1145.07
			S-80	LONG	LSS	1201.62
			S-80	BUTTRESS	LSS	1284.75
8.625	32.00	.352	H-40	SHORT	API	1189.89
			K-55	SHORT	API	1219.99
			K-55	LONG	API	1280.19
			K-55	BUTTRESS	API	1368.68
			S-80	SHORT	LSS	1327.71
			S-80	LONG	LSS	1393.30
			S-80	BUTTRESS	LSS	1489.71
8.625	36.00	.400	K-55	SHORT	API	1366.95
			K-55	LONG	API	1434.40
			K-55	BUTTRESS	API	1533.55
			S-80	SHORT	LSS	1579.79
			S-80	LONG	LSS	1657.88
			S-80	BUTTRESS	LSS	1772.67
			N-80	LONG	API	1839.08
			N-80	BUTTRESS	API	1966.56
			L-80	LONG	API	2176.32
			L-80	BUTTRESS	API	2327.40
			SS-95	LONG	LSS	2290.55
			SS-95	BUTTRESS	LSS	2449.63
			S-95	LONG	LSS	2038.59
			S-95	BUTTRESS	LSS	2180.03
			CYS-95	LONG	LSS	2240.65
			CYS-95	BUTTRESS	LSS	2396.24
			C-95	LONG	API	2365.17
			C-95	BUTTRESS	API	2529.47

OIL COUNTRY TUBULAR GOODS
PRICE LIST EFFECTIVE JUNE 01, 1980

PRICES DOLLARS PER 100 FEET - F.O.B. MILL, LONE STAR, TEXAS

SIZE O.D. INCHES	WEIGHT LBS. PER FT.	WALL INCHES	GRADE	T&C END FINISH	MFG. SPECS.	MILL PRICE
8.625	40.00	.450	N-80	LONG	API	2043.41
			N-80	BUTTRESS	API	2185.05
			L-80	LONG	API	2418.11
			L-80	BUTTRESS	API	2585.98
			SS-95	LONG	LSS	2517.81
			SS-95	BUTTRESS	LSS	2692.66
			S-95	LONG	LSS	2241.97
			S-95	BUTTRESS	LSS	2397.51
			CYS-95	LONG	LSS	2464.17
			CYS-95	BUTTRESS	LSS	2635.26
			C-95	LONG	API	2627.95
			C-95	BUTTRESS	API	2810.51
8.625	44.00	.500	N-80	LONG	API	2247.79
			N-80	BUTTRESS	API	2403.60
			L-80	LONG	API	2659.97
			L-80	BUTTRESS	API	2844.63
			SS-95	LONG	LSS	2806.39
			SS-95	BUTTRESS	LSS	3001.30
			S-95	LONG	LSS	2497.70
			S-95	BUTTRESS	LSS	2671.00
			CYS-95	LONG	LSS	2745.27
			CYS-95	BUTTRESS	LSS	2935.90
			C-95	LONG	API	2890.79
			C-95	BUTTRESS	API	3091.61
			S-105	LONG	LSS	2727.68
			S-105	BUTTRESS	LSS	2917.08
8.625	49.00	.557	N-80	LONG	API	2503.21
			N-80	BUTTRESS	API	2676.72
			L-80	LONG	API	2962.23
			L-80	BUTTRESS	API	3167.87
			SS-95	LONG	LSS	3282.53
			SS-95	BUTTRESS	LSS	3510.59
			S-95	LONG	LSS	2807.08
			S-95	BUTTRESS	LSS	3001.86
			CYS-95	LONG	LSS	3085.34
			CYS-95	BUTTRESS	LSS	3299.60
			C-95	LONG	API	3219.28
			C-95	BUTTRESS	API	3442.91
			S-105	LONG	LSS	2952.53
			S-105	BUTTRESS	LSS	3157.49
8.750	49.70	.557	SS-95	LONG	LSS	4254.88
			SS-95	BUTTRESS	LSS	4550.98
			S-95	LONG	LSS	3773.70
			S-95	BUTTRESS	LSS	4036.12
			CYS-95	LONG	LSS	4148.59
			CYS-95	BUTTRESS	LSS	4437.25

PRICE IN EFFECT AT TIME OF SHIPMENT WILL APPLY

OIL COUNTRY TUBULAR GOODS
PRICE LIST EFFECTIVE JUNE 01, 1980

PRICES DOLLARS PER 100 FEET - F.O.B. MILL, LONE STAR, TEXAS

SIZE O.D. INCHES	WEIGHT LBS. PER FT.	WALL INCHES	GRADE	T&C END FINISH	MFG. SPECS.	MILL PRICE
8.750	49.70	.557	S-105	LONG	LSS	3903.25
			S-105	BUTTRESS	LSS	4174.74
9.625	32.30	.312	H-40	SHORT	API	1229.71
9.625	36.00	.352	H-40	SHORT	API	1337.83
			K-55	SHORT	API	1371.67
			K-55	LONG	API	1439.35
			K-55	BUTTRESS	API	1538.84
			S-80	SHORT	LSS	1442.07
			S-80	LONG	LSS	1513.27
			S-80	BUTTRESS	LSS	1617.94
9.625	40.00	.395	K-55	SHORT	API	1524.34
			K-55	LONG	API	1599.56
			K-55	BUTTRESS	API	1710.13
			S-80	SHORT	LSS	1771.34
			S-80	LONG	LSS	1858.91
			S-80	BUTTRESS	LSS	1987.63
			N-80	LONG	API	2050.86
			N-80	BUTTRESS	API	2193.02
			L-80	LONG	API	2426.94
			L-80	BUTTRESS	API	2595.43
			SS-95	LONG	LSS	2496.99
			SS-95	BUTTRESS	LSS	2670.38
			S-95	LONG	LSS	2224.82
			S-95	BUTTRESS	LSS	2379.16
			CYS-95	LONG	LSS	2445.30
			CYS-95	BUTTRESS	LSS	2615.07
			C-95	LONG	API	2637.55
			C-95	BUTTRESS	API	2820.78
9.625	43.50	.435	N-80	LONG	API	2230.34
			N-80	BUTTRESS	API	2384.94
			L-80	LONG	API	2639.33
			L-80	BUTTRESS	API	2822.56
			SS-95	LONG	LSS	2696.66
			SS-95	BUTTRESS	LSS	2883.90
			S-95	LONG	LSS	2404.45
			S-95	BUTTRESS	LSS	2571.24
			CYS-95	LONG	LSS	2642.72
			CYS-95	BUTTRESS	LSS	2826.19
			C-95	LONG	API	2868.37
			C-95	BUTTRESS	API	3067.63
9.625	47.00	.472	N-80	LONG	API	2409.79
			N-80	BUTTRESS	API	2576.83
			L-80	LONG	API	2851.69
			L-80	BUTTRESS	API	3049.66

LONE STAR STEEL COMPANY

OIL COUNTRY TUBULAR GOODS
PRICE LIST EFFECTIVE JUNE 01, 1980

PRICES DOLLARS PER 100 FEET - F.O.B. MILL, LONE STAR, TEXAS

SIZE O.D. INCHES	WEIGHT LBS. PER FT.	WALL INCHES	GRADE	T&C END FINISH	MFG. SPECS.	MILL PRICE
9.625	47.00	.472	SS-95	LONG	LSS	3080.62
			SS-95	BUTTRESS	LSS	3294.62
			S-95	LONG	LSS	2734.82
			S-95	BUTTRESS	LSS	2924.61
			CYS-95	LONG	LSS	3005.95
			CYS-95	BUTTRESS	LSS	3214.72
			C-95	LONG	API	3099.16
			C-95	BUTTRESS	API	3314.46
9.625	53.50	.545	N-80	LONG	API	2743.04
			N-80	BUTTRESS	API	2933.18
			L-80	LONG	API	3246.06
			L-80	BUTTRESS	API	3471.41
			SS-95	LONG	LSS	3723.26
			SS-95	BUTTRESS	LSS	3982.02
			S-95	LONG	LSS	3192.96
			S-95	BUTTRESS	LSS	3414.59
			CYS-95	LONG	LSS	3501.60
			CYS-95	BUTTRESS	LSS	3744.84
			C-95	LONG	API	3527.75
			C-95	BUTTRESS	API	3772.82
			S-105	LONG	LSS	3417.81
			S-105	BUTTRESS	LSS	3655.18
9.625	58.40	.595	SS-95	LONG	LSS	4221.21
			SS-95	BUTTRESS	LSS	4514.65
			S-95	LONG	LSS	3735.36
			S-95	BUTTRESS	LSS	3994.79
			CYS-95	LONG	LSS	4105.98
			CYS-95	BUTTRESS	LSS	4391.35
			S-105	LONG	LSS	3877.33
			S-105	BUTTRESS	LSS	4146.70
9.625	61.10	.625	SS-95	LONG	LSS	4507.41
			SS-95	BUTTRESS	LSS	4820.79
			S-95	LONG	LSS	4044.96
			S-95	BUTTRESS	LSS	4325.97
			CYS-95	LONG	LSS	4446.40
			CYS-95	BUTTRESS	LSS	4755.51
			S-105	LONG	LSS	4301.77
			S-105	BUTTRESS	LSS	4600.76
9.750	59.20	.595	SS-95	LONG	LSS	5032.34
			SS-95	BUTTRESS	LSS	5382.53
			S-95	LONG	LSS	4501.45
			S-95	BUTTRESS	LSS	4814.48
			CYS-95	LONG	LSS	4948.64
			CYS-95	BUTTRESS	LSS	5292.97
			S-105	LONG	LSS	4666.21

LONE STAR STEEL COMPANY

OIL COUNTRY TUBULAR GOODS
PRICE LIST EFFECTIVE JUNE 01, 1980

PRICES DOLLARS PER 100 FEET - F.O.B. MILL, LONE STAR, TEXAS

SIZE O.D. INCHES	WEIGHT LBS. PER FT.	WALL INCHES	GRADE	T&C END FINISH	MFG. SPECS.	MILL PRICE
9.750	59.20	.595	S-105	BUTTRESS	LSS	4990.77
9.875	62.80	.625	SS-95	LONG	LSS	5172.02
			SS-95	BUTTRESS	LSS	5531.86
			S-95	LONG	LSS	4665.07
			S-95	BUTTRESS	LSS	4989.43
			CYS-95	LONG	LSS	5128.44
			CYS-95	BUTTRESS	LSS	5485.23
			S-105	LONG	LSS	4950.01
			S-105	BUTTRESS	LSS	5294.31
10.750	32.75	.279	H-40	SHORT	API	1250.60
10.750	40.50	.350	H-40	SHORT	API	1504.07
			K-55	SHORT	API	1542.12
			K-55	BUTTRESS	API	1730.07
			S-80	SHORT	LSS	1687.75
			S-80	BUTTRESS	LSS	1893.69
10.750	45.50	.400	K-55	SHORT	API	1733.64
			K-55	BUTTRESS	API	1944.93
			S-80	SHORT	LSS	1912.36
			S-80	BUTTRESS	LSS	2145.73
10.750	51.00	.450	K-55	SHORT	API	1937.79
			K-55	BUTTRESS	API	2173.95
			S-80	SHORT	LSS	2330.29
			S-80	BUTTRESS	LSS	2614.93
			N-80	SHORT	API	2607.09
			N-80	BUTTRESS	API	2787.80
			L-80	SHORT	API	3085.16
			L-80	BUTTRESS	API	3299.34
			SS-95	SHORT	LSS	3175.86
			SS-95	BUTTRESS	LSS	3396.39
			S-95	SHORT	LSS	2800.04
			S-95	BUTTRESS	LSS	2994.26
			CYS-95	SHORT	LSS	3077.49
			CYS-95	BUTTRESS	LSS	3291.13
			C-95	SHORT	API	3352.88
			C-95	BUTTRESS	API	3585.80
10.750	55.50	.495	S-80	SHORT	LSS	2548.00
			S-80	BUTTRESS	LSS	2859.25
			N-80	SHORT	API	2837.14
			N-80	BUTTRESS	API	3033.80
			L-80	SHORT	API	3357.40
			L-80	BUTTRESS	API	3590.48
			SS-95	SHORT	LSS	3678.17
			SS-95	BUTTRESS	LSS	3933.70

OIL COUNTRY TUBULAR GOODS
PRICE LIST EFFECTIVE JUNE 01, 1980

PRICES DOLLARS PER 100 FEET - F.O.B. MILL, LONE STAR, TEXAS

SIZE O.D. INCHES	WEIGHT LBS. PER FT.	WALL INCHES	GRADE	T&C END FINISH	MFG. SPECS.	MILL PRICE
10.750	55.50	.495	S-95	SHORT	LSS	3264.48
			S-95	BUTTRESS	LSS	3491.05
			CYS-95	SHORT	LSS	3588.15
			CYS-95	BUTTRESS	LSS	3837.38
			C-95	SHORT	API	3648.74
			C-95	BUTTRESS	API	3902.21
10.750	60.70	.545	SS-95	SHORT	LSS	4067.25
			SS-95	BUTTRESS	LSS	4349.83
			S-95	SHORT	LSS	3625.14
			S-95	BUTTRESS	LSS	3876.78
			CYS-95	SHORT	LSS	3984.62
			CYS-95	BUTTRESS	LSS	4261.42
10.750	65.70	.595	SS-95	SHORT	LSS	4415.34
			SS-95	BUTTRESS	LSS	4722.11
			S-95	SHORT	LSS	3950.38
			S-95	BUTTRESS	LSS	4224.61
			CYS-95	SHORT	LSS	4342.13
			CYS-95	BUTTRESS	LSS	4643.78
			S-105	SHORT	LSS	4198.45
			S-105	BUTTRESS	LSS	4490.04
10.750	71.10	.650	SS-95	SHORT	LSS	4763.68
			SS-95	BUTTRESS	LSS	5094.65
			S-95	SHORT	LSS	4143.43
			S-95	BUTTRESS	LSS	4430.98
			CYS-95	SHORT	LSS	4554.22
			CYS-95	BUTTRESS	LSS	4870.53
			S-105	SHORT	LSS	4542.65
			S-105	BUTTRESS	LSS	4858.15
11.750	42.00	.333	H-40	SHORT	API	1605.12
11.750	47.00	.375	K-55	SHORT	API	1798.54
			K-55	BUTTRESS	API	2017.76
			S-80	SHORT	LSS	1985.81
			S-80	BUTTRESS	LSS	2228.16
11.750	54.00	.435	K-55	SHORT	API	2057.86
			K-55	BUTTRESS	API	2308.67
			S-80	SHORT	LSS	2203.43
			S-80	BUTTRESS	LSS	2472.22
11.750	60.00	.489	K-55	SHORT	API	2276.63
			K-55	BUTTRESS	API	2554.09
			S-80	SHORT	LSS	2685.90
			S-80	BUTTRESS	LSS	3013.91
			N-80	SHORT	API	3062.95

OIL COUNTRY TUBULAR GOODS
PRICE LIST EFFECTIVE JUNE 01, 1980

PRICES DOLLARS PER 100 FEET - F.O.B. MILL, LONE STAR, TEXAS

SIZE O.D. INCHES	WEIGHT LBS. PER FT.	WALL INCHES	GRADE	T&C END FINISH	MFG. SPECS.	MILL PRICE
11.750	60.00	.489	N-80	BUTTRESS	API	3275.26
			L-80	SHORT	API	3624.61
			L-80	BUTTRESS	API	3876.23
			SS-95	SHORT	LSS	3811.82
			SS-95	BUTTRESS	LSS	4076.55
			S-95	SHORT	LSS	3405.00
			S-95	BUTTRESS	LSS	3641.25
			CYS-95	SHORT	LSS	3742.50
			CYS-95	BUTTRESS	LSS	4002.38
			C-95	SHORT	API	3939.14
			C-95	BUTTRESS	API	4212.78
11.750	65.00	.534	SS-95	SHORT	LSS	4232.70
			SS-95	BUTTRESS	LSS	4526.71
			S-95	SHORT	LSS	3785.28
			S-95	BUTTRESS	LSS	4047.97
			CYS-95	SHORT	LSS	4160.56
			CYS-95	BUTTRESS	LSS	4449.52
11.750	71.00	.582	SS-95	SHORT	LSS	4864.90
			SS-95	BUTTRESS	LSS	5202.96
			S-95	SHORT	LSS	4299.19
			S-95	BUTTRESS	LSS	4597.65
			CYS-95	SHORT	LSS	4725.56
			CYS-95	BUTTRESS	LSS	5053.86
11.875	71.80	.582	SS-95	SHORT	LSS	5998.16
			SS-95	BUTTRESS	LSS	6415.52
			S-95	SHORT	LSS	5376.28
			S-95	BUTTRESS	LSS	5750.11
			CYS-95	SHORT	LSS	5910.32
			CYS-95	BUTTRESS	LSS	6321.53
13.375	48.00	.330	H-40	SHORT	API	1897.83
13.375	54.50	.380	K-55	SHORT	API	2148.44
			K-55	BUTTRESS	API	2410.41
			S-80	SHORT	LSS	2333.70
			S-80	BUTTRESS	LSS	2618.54
13.375	61.00	.430	K-55	SHORT	API	2394.82
			K-55	BUTTRESS	API	2686.82
			S-80	SHORT	LSS	2593.07
			S-80	BUTTRESS	LSS	2909.55
13.375	68.00	.480	K-55	SHORT	API	2659.10
			K-55	BUTTRESS	API	2983.31
			S-80	SHORT	LSS	3096.57
			S-80	BUTTRESS	LSS	3474.80

PRICE IN EFFECT AT TIME OF SHIPMENT WILL APPLY

OIL COUNTRY TUBULAR GOODS
PRICE LIST EFFECTIVE JUNE 01, 1980

PRICES DOLLARS PER 100 FEET - F.O.B. MILL, LONE STAR, TEXAS

SIZE O.D. INCHES	WEIGHT LBS. PER FT.	WALL INCHES	GRADE	T&C END FINISH	MFG. SPECS.	MILL PRICE
13.375	68.00	.480	C-75	SHORT	API	4050.40
			C-75	BUTTRESS	API	4331.55
			N-80	SHORT	API	3577.89
			N-80	BUTTRESS	API	3825.96
			L-80	SHORT	API	4234.16
			L-80	BUTTRESS	API	4528.17
			C-95	SHORT	API	4601.67
			C-95	BUTTRESS	API	4921.41
13.375	72.00	.514	S-80	SHORT	LSS	3294.83
			S-80	BUTTRESS	LSS	3697.29
			N-80	SHORT	API	3788.37
			N-80	BUTTRESS	API	4051.04
			L-80	SHORT	API	4483.25
			L-80	BUTTRESS	API	4794.56
			SS-95	SHORT	LSS	4677.87
			SS-95	BUTTRESS	LSS	5002.80
			S-95	SHORT	LSS	4309.28
			S-95	BUTTRESS	LSS	4608.41
			CYS-95	SHORT	LSS	4736.61
			CYS-95	BUTTRESS	LSS	5065.65
			C-95	SHORT	API	4872.38
			C-95	BUTTRESS	API	5210.93
13.375	80.70	.580	S-80	BUTTRESS	LSS	4234.57
			SS-95	BUTTRESS	LSS	6034.07
			S-95	BUTTRESS	LSS	5318.71
			CYS-95	BUTTRESS	LSS	5846.56
13.375	86.00	.625	SS-95	BUTTRESS	LSS	7231.27
			S-95	BUTTRESS	LSS	6471.05
			CYS-95	BUTTRESS	LSS	7113.85
13.500	81.40	.580	SS-95	BUTTRESS	LSS	7462.22
			S-95	BUTTRESS	LSS	6677.27
			CYS-95	BUTTRESS	LSS	7340.92
13.625	88.20	.625	SS-95	BUTTRESS	LSS	8057.94
			S-95	BUTTRESS	LSS	7232.41
			CYS-95	BUTTRESS	LSS	7951.25
16.000	65.00	.375	H-40	SHORT	API	2696.67
			H-40	BUTTRESS	API	3025.70
16.000	75.00	.438	K-55	SHORT	API	3143.44
			K-55	BUTTRESS	API	3527.03
16.000	84.00	.495	K-55	SHORT	API	3489.63
			K-55	BUTTRESS	API	3915.41

PRICE IN EFFECT AT TIME OF SHIPMENT WILL APPLY

VITA

Stephen Lawrence Ege

Candidate for the Degree of

Master of Business Administration

Report: A LINEAR MATHEMATICAL MODEL TO OPTIMIZE BUYING, SHIPPING AND STORING OIL FIELD TUBULARS

Major Field: Business Administration

Biographical:

Personal Data: Born in Kansas City, Missouri, July 12, 1953, the son of William and Norma Ege.

Education: Graduated from Shawnee Mission South High School, Overland Park, Kansas, May, 1971; received the Bachelor of Science degree from the University of Kansas with a major in Chemical Engineering, May, 1975; completed requirements for the Master of Business Administration degree at Oklahoma State University, July, 1980.

Professional Experience: Employed by the Phillips Petroleum Company 1975-1980. From 1975-1977 assigned to Odessa, Texas in both process and production work; from 1977-1980 assigned to Bartlesville, Oklahoma doing feasibility economics for oil and gas projects for Europe and Africa.