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AN ALGORITHMIC APPROACH TO SCHEDULING

A MULTI-PRODUCT PIPELINE SYSTEM

by

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CHAPTER I

INTRODUCTION

Ever since that first oil well was drilled nearly 110 years ago, the oil industry has been in constant state of change. Spectacular changes and sweeping successes were achieved in the fields of oil exploration, drilling and refining. As population and standards of living grew up all over the world, markets for oil products expanded steadily and transportation of crude oil from oil fields to refineries and finished products from refineries to customers became a problem of concern and received a great attention. Tank trucks, rail cars, barges, ocean tankers and pipelines were put to use. With the advancement of technology, capacities of these modes of transport were improved and reduction in initial investment and operating cost per ton-mile resulted. Also recent development of Operations Research techniques and methods of Management Sciences have enabled the oil industry to reduce operating costs substantially in all phases of refinery management. As an example, linear programming formulations are widely used in the selection and blending of crude stocks to be refined to meet product demands within crude availability and equipment throughput restrictions. Numerous scheduling techniques have also been applied profitably for routing of tank trucks and preparation of time tables for ocean tankers.

This research focusses attention on one mode of oil transportation, namely, pipelines. In the year 1900 there were some 6800 miles of interstate pipelines in U.S.A., used exclusively for transportation of crude oil [2]. Even at that time, pipelines were of major importance to American petroleum industry, but to the general public the presense of these vital underground arteries of oil transportation was for the most part, unknown. Between the years 1915 and 1931, the American oil industry took on many of its present day characteristics in terms of organization and structures. New and vast crude supplies were discovered and refineries switched to integrated form of operations. Automobile age began and there was an upward surge of demand for all petroleum products. Construction rate of pipelines in the U.S.A. trippled in this period [2] and many oil companies began to use pipelines for transporting their finished products to markets. These pipelines were later came to be known as product pipelines. The integrated refineries operated on continuous basis as such an operation proved to be of substantial economic advantage. Continuous operation stressed the need for continuous inflow of crude and outflow of refined products and this gave added impetus to the growth of pipeline systems.

End of World War II saw unforseen growth in the demand of petroleum products in this country and many new pipeline companies, some unaffiliated to any refinery, began to emerge. These pipeline companies served either a group of refineries or gas plants. A gas plant essentially performs the functions of a refinery, but is much smaller than a refinery both in size and scope. The pipeline companies were responsible for many great innovations in the construction and operation of pipelines. By 1950, throughput of a pipeline was largely increased by increasing its diameters to 20"-24". Product pipelines were also used as wet-lines which meant that they carried gaseous as well as liquid products. Multi-product pipelines became common and these carried a variety of products such as kerosene gasoline and liquid petroleum gas at the same time. The resulting problems of identification of products and directing them to proper storage tanks were solved by the use of radio active tracers [2].

The diversity in the use of a pipeline naturally leads to complexity in its operations. Corrosion, prevention of leaks and safety in operation are still major problems. The effect of pipelines, especially those which are above ground and operate at a higher temperature than their surroundings, on environment is a subject of considerable research. Though the problem of identification of products in a multi-product pipeline is solved, the problem of scheduling these products through the pipeline such that degradation of products due to intermixing is minimized, has received little attention. This research is directed towards finding a solution for such a problem posed by a major pipeline company in the U.S.A.

1.1 Definition of the Problem

In the pipeline system under consideration there are nine pump stations. Each of these pump stations is connected to a gas plant. At each pump station, there are storage tanks, equal in number to the number of products manufactured by its gas plant. Each tank can store only one type of product and has a safe maximum and safe minimum level. The pump at each pump station has a fixed pumping capacity. Figure 1.1 gives the schematic representation of the complete pipeline system.

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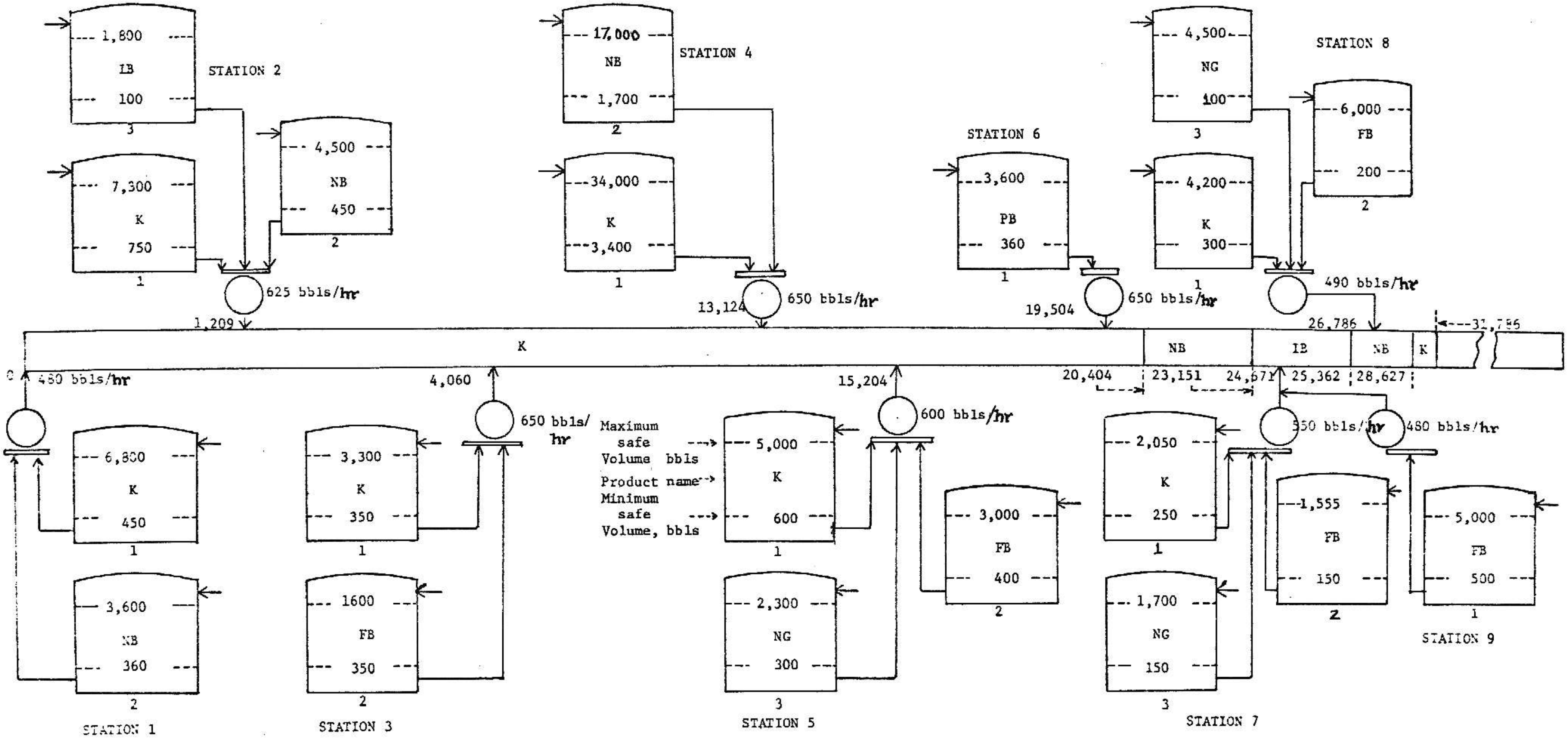


Product names:	Propane (K)	Iso-Butane (IB)	Natural Butane (NB)	Propane-Butane (PB)	Natural Gas (NG)	Field-Butane (FB)
Numeric code of products:	1	2	3	4	5	6

Fig. 1.1. Schematic Representation of the Pipeline System.

All the products pumped through the pipeline by the pump stations are delivered at one delivery point. There is no restriction on the quantity or the type of product to be pumped to the delivery point. Each gas plant produces its products at constant rates during a fixed and known length of time. Table 1.1 gives typical production rates of the gas plants.

In a sequence of pumping of products from the pump stations, only one pump can be kept running at a time. When a pump is running all the products in the downstream of the pump station are moved forward while the products in the upstream side will remain still. For example, if a pump at station 3 is running, all the products in the pipeline between stations 3 and 9 are pushed forward, while the products between stations 1 and 3 remain still.

The various assumptions in regard to operation of the pipeline can be summarized as follows:

1. Each storage tank has a safe top level and a safe bottom level.
2. Only one type of product can be stored in each storage tank.
3. During a given length of time, each gas plant produces a given set of products at constant rates. The plants can not be shut down and the rate of production can not be varied in order to facilitate a desired sequence of pumping.
4. Only one pump is kept running at any time. While one pump is running, all the other pumps are shut down.

Table 1.1. Typical Production Rates at the Gas Plants

Gas Plant/ Pump Station No.	Storage Tank No.	Alphabetic Code of Product	Typical Production Rate bbls/day	Maximum Safe Volume bbls	Minimum Safe Volume bbls	Capacity of the Pump at the Pump Station bbls/hour
1	1	K	1,970	6,800	450	480
	2	NB	0	3,600	360	
2	1	K	1,750	7,300	750	625
	2	NB	1,000	4,500	450	
	3	IB	395	1,800	100	
3	1	K	475	3,300	350	650
	2	FB	200	1,600	250	
4	1	K	0	34,000	3,400	650
	2	NB	0	17,000	1,700	
5	1	K	620	5,000	600	600
	2	FB	380	3,000	400	
	3	NG	375	2,300	300	
6	1	PB	315	3,600	360	650
7	1	K	530	2,050	250	550
	2	FB	305	1,555	150	
	3	NG	250	1,700	150	
8	1	K	340	4,200	300	490
	2	FB	300	6,000	200	
	3	NG	0	4,500	100	
9	1	FB	0	5,000	500	480

5. At the end of the pipeline, there is no limit on the amount of any product to be delivered at any time.
6. In the sequence of flow of different products in the pipeline, Propane-Butane Casinghead Gas (PB) must always be followed and preceded by Propane (K).
8. The variations in the pipeline capacity between station to station, due to compressibility of products and pipeline friction, are negligible.
9. The same product produced by various gas plants has similar specifications.

In any sequence of pumping, different products are discharged into the pipeline and therefore there will always be a series of different products present in it. The type of products and exact location of each product change from time to time. When two products of different types flow one behind other in the pipeline, there will be intermixing of the two products, resulting in degradation of higher grade product between the two products. The degraded product and its volume are known as interface and interface volume, respectively. The exact amount of interface volume depends upon the types of products involved at the interface.

1.2 Types of Interface Losses

Consider the interface of products K and FB. FB is a higher grade product than K. When the two of them are mixed, the mixture is sold at the sale price of K. The interface volume created when FB flows behind K is the same as that when K flows behind FB. To illustrate, if the sale price of FB and K are \$3.50 and 3.00 per bbl (barrel) respectively, and if the volume of interface is 200 bbls composed of

40% K and 60% FB, the loss due to interface is equal to (0.60x200)(3.50-3.00) = \$60.00. It should be pointed out that it is not known how much degradation occurs for all products that could be involved in an interface.

While it is true that an interface is created by two products of different types flowing one behind the other, the primary cause of an interface is discharging into the pipeline, a product which is different in type to that already present, in front of the pump station. The number of products, number of interfaces, and their volumes in the pipeline immediately after a pumping depend entirely upon the exact status of the pipeline in front of the pump station, preceding each pumping. Therefore, a count of total interfaces created during a sequence of pumping can easily be kept if the exact status of the pipeline in front of a pump station just before a product is pumped from it, is known.

The term 'types of interface' refers to the status of the pipeline in front of a pump station just before a product is pumped from the station and to the interfaces created as a result of pumping. The term 'one interface' refers to the normal volume of interface created when any two products of different types flow one behind the other in the pipeline. '1/2 interface' therefore, refers to half the normal volume of interface. The various types of interfaces created in the pipeline system and the conditions under which they are created are as follows.

Interface Type 0. This type of interface is created when product, say X is pumped from pump station 1. The same type of interface is created when product X is pumped from any intermediate station provided at least 200 bbls of product X is present on either side of the station. Figures 1.2a and 1.2b represent this situation. The number of additional interfaces created in these conditions is zero.

Interface Type 1. This type of interface is created when product, say Y is pumped from any intermediate pump station. The number of interfaces created in this condition is two, see Figure 1.3.

Interface Type 2. At any intermediate pump station, if product, say Y is pumped either immediately after product X, or before any product from an upstream station is pumped, type 2 interface is created. The number of additional interfaces created is one, see Figure 1.4a and 1.4b.

Interface Type 3. This type of interface is created when product, say X is pumped into a previously formed interface rather than a product. The product on the upstream side of the interface, in this case is X. The number of additional interfaces created is half, see Figure 1.5a.

Interface Type 4. If product, say Y is pumped from any station into an interface, new type of interface is created. The product on the downstream side of the interface in this case is Y and the number of additional interfaces created is half, see Figure 1.5b.

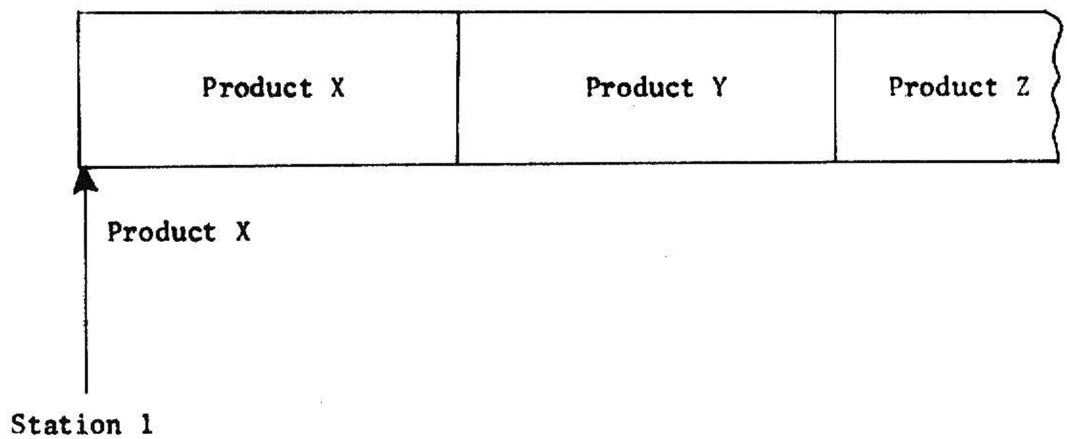
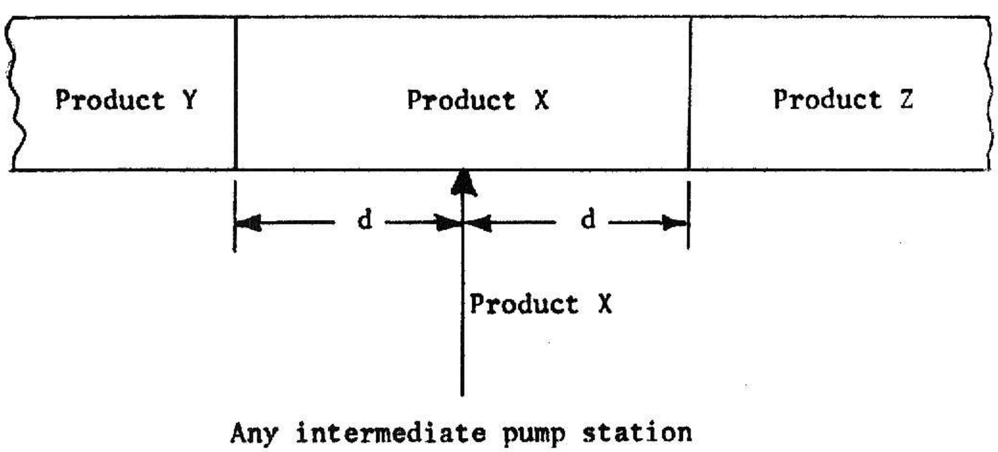


Fig. 1.2a.



(d $\geq$ 200 bbls)

Fig. 1.2b.

Fig. 1.2. Details of Type 0 Interface

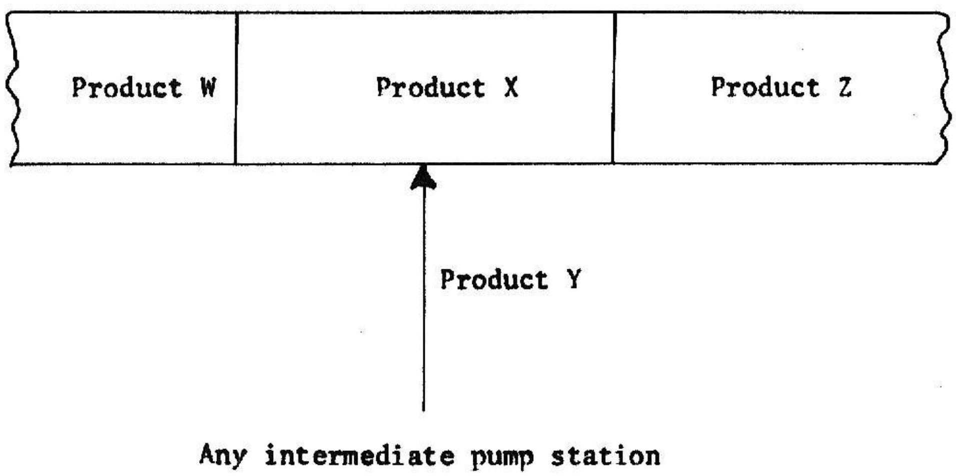


Fig. 1.3. Details of Type 1 Interface

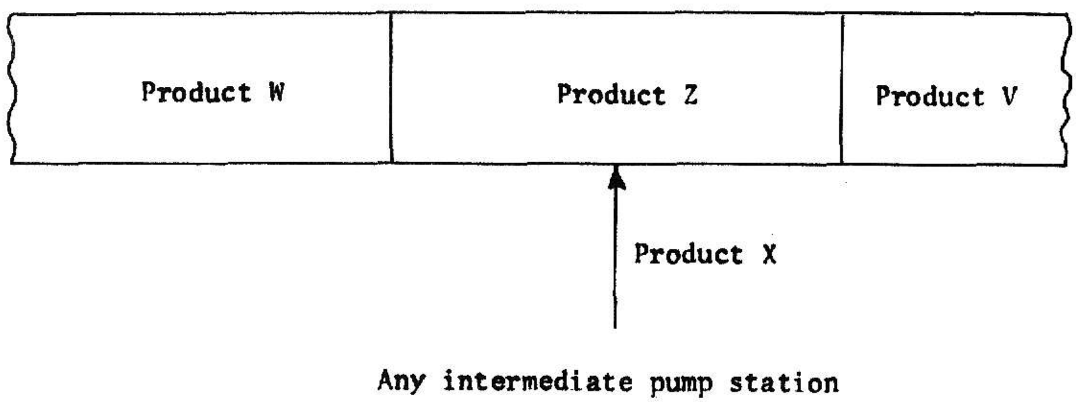


Fig. 1.4a. Before pumping product X.

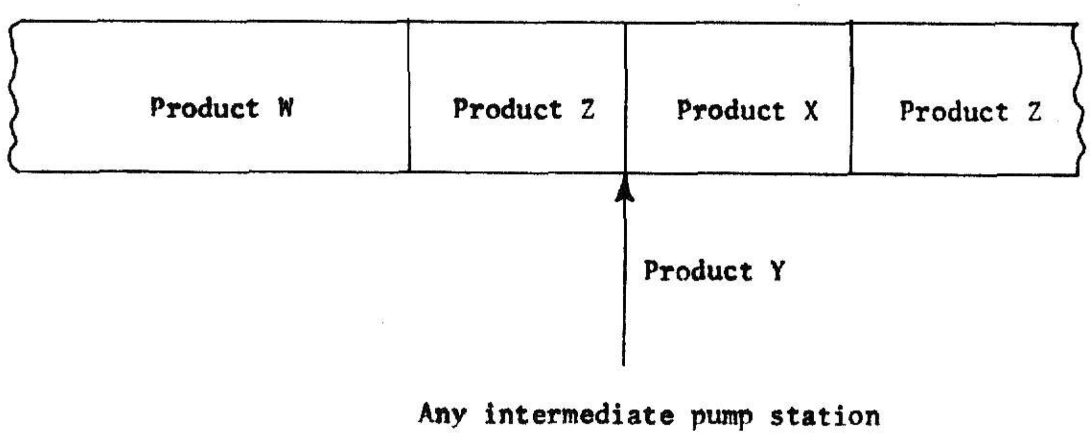


Fig. 1.4b. After pumping product X but before pumping product Y.

Fig. 1.4. Details of Type 2 Interface

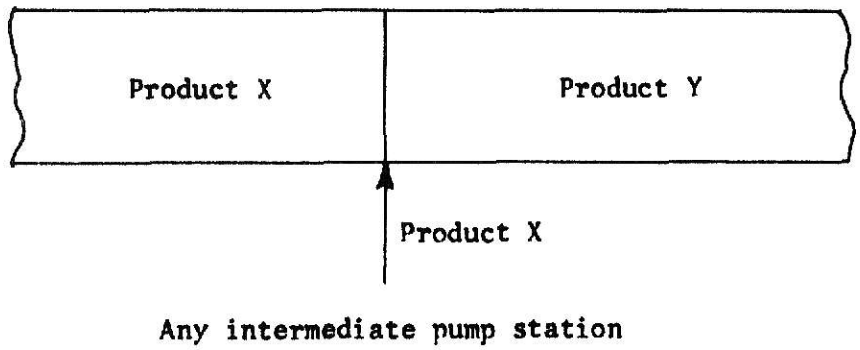


Fig. 1.5a. Details of type 3 interface.

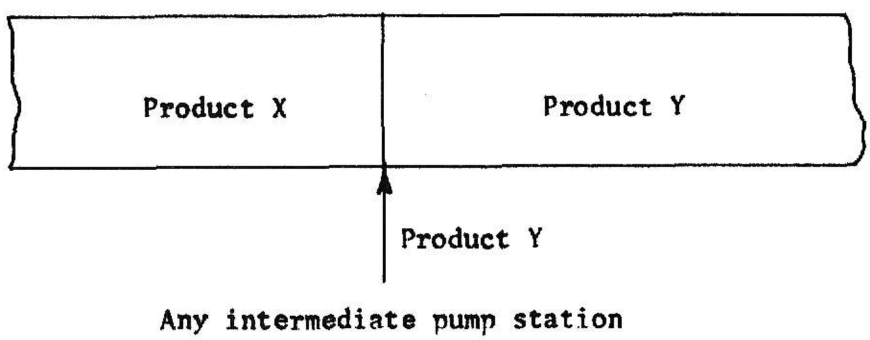


Fig. 1.5b. Details of type 4 interface

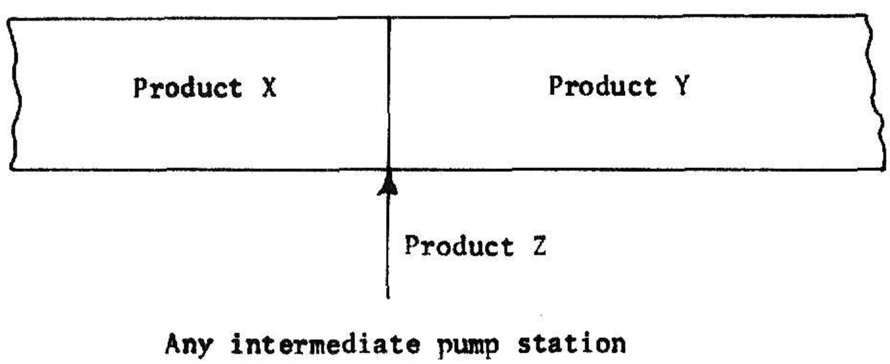


Fig. 1.5c. Details of type 5 interface.

Fig. 1.5. Details of Type 3, 4, and 5 Interfaces

Interface Type 5. This type of interface is created when product, say Z is pumped into an interface. The product pumped is neither the upstream nor the downstream product of the interface. The number of additional interfaces created is two, see Figure 1.5c.

Interface Type 6. This type of interface will be created only at pump station 1, when product, say X is pumped. The number of additional interfaces created is one. Figure 1.6 shows that this type of interface is different from Type 1 because under Type 1 conditions two additional interfaces are created.

Interface Type 7. This type of interface is created when product, say X is pumped from any intermediate station, if the volume of product X in the pipeline, on either downstream or upstream side of the station is less than 200 bbls. The number of additional interfaces created is two. This condition, however, does not apply to pump station 1, see Figure 1.7.

In discussing interfaces so far, only the number of interfaces created for each type has been considered. However, it is easier and more meaningful to discuss interfaces in terms of volumes rather than numbers. It is known, with a fair degree of accuracy, that when product K follows product PB in the pipeline, the volume of interface created is 200 bbls. It will be reasonable, therefore, to assume that when any two different products flow one behind other in the pipeline the volume of interface created is 200 bbls.

The various types of interfaces, and conditions under which they are created are summarized in Table 1.2.

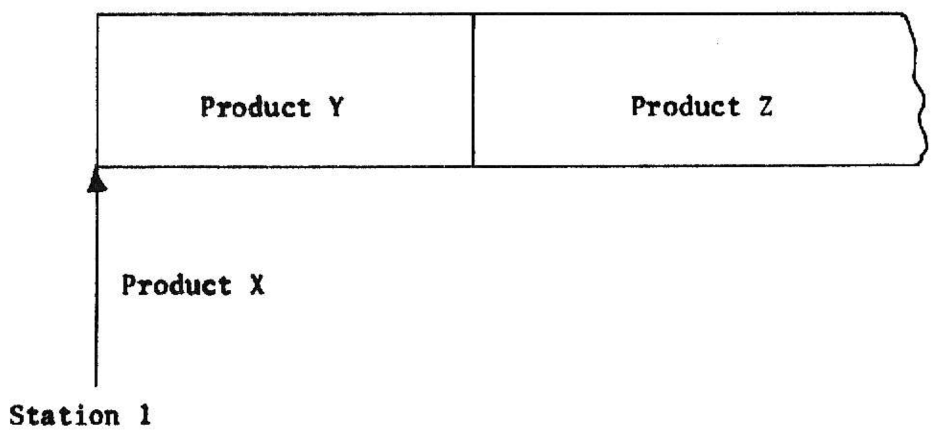


Fig. 1.6. Details of Type 6 Interface

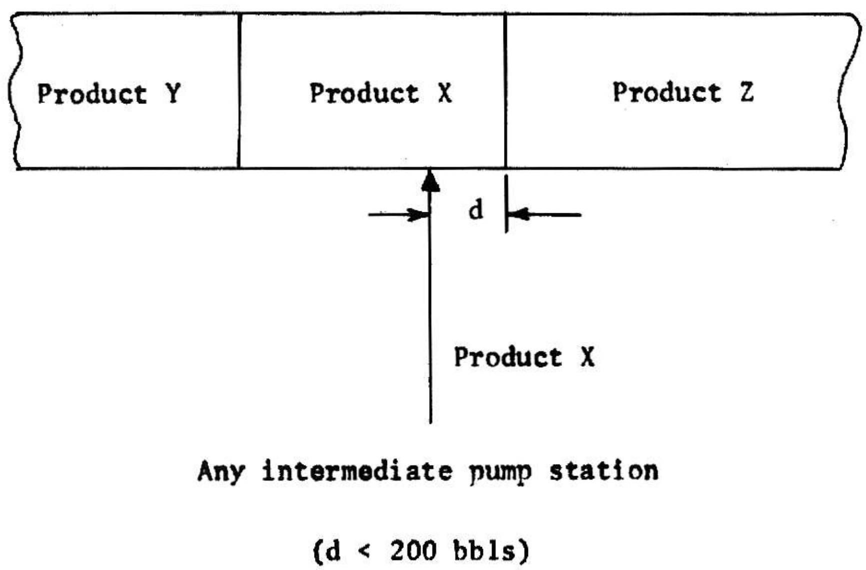


Fig. 1.7. Details of Type 7 Interface

Table 1.2 Summarized Details of Types of Interfaces

Type of interface	No. of interfaces created	Description
Type 0	0	The product pumped from a pump station is the same as the product present in the pipeline, in front of the station.
Type 1	2	The product pumped from a pump station is not the same as the product present in the pipeline, in front of the station. This type of interface will never be created at pump station No. 1.
Type 2	1	A product is pumped into an interface; the interface was created by some other product, pumped from the same station.
Type 3	1/2	A product pumped into an interface is the same as the product present on the upstream side of the interface.
Type 4	1/2	A product pumped into an interface is the same as the product present on the down stream side of the interface.
Type 5	2	A product pumped into an interface is not the same as both the upstream and downstream products of the interface.
Type 6	1	The product pumped is not the same as the product present in the pipeline in front of the pump station. This type of interface can be created only at pump station No. 1.
Type 7	2	The product pumped is the same as the product present in the pipeline, in front of the station. But the volume of the product in the pipeline, is less than 200 bbls on either the downstream or upstream side of the station.

1.3 Scheduling of the Pipeline

As mentioned earlier, the production rates at the gas plants remain constant at given levels for a known and fixed length of time. For convenience, this length of time will be referred to as a production period. A schedule is simply a sequence of pumpings during a production period. The pipeline is said to be idle when no product is pumped through it.

A schedule can either be stationary or non-stationary. A stationary schedule is one in which pumpings follow one another without any idle periods in between the pumpings. Schedule period in this case is defined as the sum of pumping times. A non-stationary schedule, however, can have idle periods in between the pumpings and schedule period in this case, is defined as the sum of total pumping times and total idle times. There is no strict restriction on the number of pumpings and individual pumping times during a schedule period. However, in order to reduce the transient impulses of current due to frequent startings of the pumps and to maintain the stability of the electrical system, a pump is kept running for at least 15 minutes. A feasible schedule is defined as the schedule which maintains the levels of products in all tanks in between the safe maximum and safe minimum, at all times.
The optimal schedule is one which minimizes the total interface loss in the pipeline.

The Scheduling and Dispatching Division of the Pipeline Company currently uses a computer program which tabulates a schedule in detail. The information about production rates at the gas plants and the initial inventory in storage tanks are fed in as input data to the program. In addition, the scheduler provides a predetermined sequence of products to be pumped as input data. The program then calculates the batch sizes, updates the status of pipeline, and indicates the infeasibilities, if any (that is, the level of any product in its tank going above or below safe levels). If any infeasibilities occur, the sequence of products to be pumped and their batch sizes are adjusted by hand in order to make the schedule feasible. The predetermined sequence supplied as input to the computer program is prepared by an experienced scheduler, using his judgement and hand calculations. The scheduler attempts to minimize the interface losses in the predetermined sequence based on his knowledge and experience. However, it is not known whether the schedules prepared by this procedure are the best schedules or not, from the view point of minimizing interface losses.

In general, two schedules are prepared each week. The first schedule might start on Monday at 6:00 am. and end on Wednesday at midnight, lasting approximately 66 hours. The second schedule might start on Thursday at 6:00 am and end on Saturday at midnight, lasting approximately 66 hours. These schedule periods vary from week to week. The pipeline is idle during the intermediate periods, while the plants continue their production. A typical schedule is shown in Table 1.3. The schedule starts with pumping of 700 bbls of FB from station 3. A batch of 3500 bbls of NB is then pumped from station 2. After its completion, another batch of 1380 bbls of IB is pumped from station 2 and so on. The last batch in the schedule is 1855 bbls of K pumped from station 7.

Table 1.3. A Typical Schedule Prepared by the Pipeline Company

Pumping No.	Product Code	Station No.	Volume Pumped bbls
1	FB	3	700
2	NB	2	3500
3	IB	2	1380
4	K	2	6125
5	K	1	900
6	FB	5	1330
7	K	3	1660
8	NG	5	1310
9	K	5	2170
10	K	1	3500
11	FB	7	1070
12	PB	6	1100
13	FB	8	1050
14	K	1	1900
15	NG	7	875
16	K	8	1290
17	K	1	600
18	K	7	1855

For the purpose of analysis, data of 7 consecutive production periods, lasting for approximately 504 hours, were obtained from the pipeline company. The data also includes the details of the schedules during these periods.

1.4 Proposed Research.

As stated previously, the interfaces created in the pipeline represent a loss of revenue to the gas plants in the pipeline system. The loss can be minimized, if the average ratio of interface volume created to the total volume of products pumped is minimized. The objective of this research is, therefore, to (1) develop an algorithm capable of generating schedules which would minimize the ratio, and (2) test the proposed algorithm by means of a simulation program. In order to compare the ratio obtained from the proposed algorithm, it would also be necessary to obtain the similar ratio from the sample schedules furnished by the pipeline company, by means of a computer program.

CHAPTER II

CURRENT SCHEDULING PROCEDURE

Before a description of pipeline company's schedules is given and an analysis made, it will be of interest to discuss briefly the way in which the scheduler gathers information in order to prepare his schedules.

The scheduler's office is located away from the pump stations and he communicates with them by means of a telephone. Adequate facilities are available at the pump stations to measure the levels of products in storage tanks and the rate of input to each of them. At a predetermined time the scheduler calls each station in turn and collects information on level of products in storage tanks and rate of input to them. If a maintenance job is planned to be done either at any of the pump stations or at any part of the pipeline itself during the planned schedule period, he obtains the starting and finishing times of such a job. This, along with the tank status data and a pumping sequence aimed at minimizing interface loss, form the input data to the computer program. Approximately three hours after collecting the data the scheduler calls the pump stations again and gives them instructions about the time at which a particular product should be pumped and the duration of pumping. He also contacts the delivery point and tells them the time at which each product or interface will reach them. At the time a new product or an interface is known to arrive at the delivery point, samples are drawn from the pipeline and checked for the type of product. If it is a new product, then it is diverted to appropriate storage facility or another pipeline. When a new interface arrives, regardless of its constituent products, it is directed to one storage tank.

Table 2.1 gives the details on volumes in storage tanks and production rates per day, prevailing at the beginning of seven consecutive production periods. The schedules prepared are given in Table 2.2 through 2.8. In the previous chapter, it was mentioned that the production rates at all gas plants remain constant at known levels from the beginning to the end of a production period. However, this is not true in the case of gas plants No. 1, 4, and 9. A careful examination of the tank status data reveals that at the beginning of the second production period, the volume of product K in tank 1 in station 4 is 7,400 bbls, which is well above the safe minimum level of 3,400 bbls, implying that this product was produced during the first production period. But the first production period data shows the production rate of this product as 0. This product was of course made during the first production period but the data does not reflect this fact because the production started sometime during the schedule period and the scheduler was unaware of it as he obtains information only at the beginning of a production period.

The production period itself does not form a part of the data because the schedules prepared are stationary with schedule period generally much less than the production period. It is quite possible that the level of products in storage tanks updated with previous period production rates, will differ from actual levels at the beginning of the succeding

Table 2.1

Details of Production Rates and Initial Volumes in Tanks at the Beginning of Seven Consecutive Production Periods

Station No.	Tank No.	Product type code	Production periods						
			Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7
			[96 hrs]	[48 hrs]	[120 hrs]	[58 hrs]	[110 hrs]	[72 hrs]	[Not known]
1	1	1	1,950* (4,429)†	2,310* (5,750)†	0* (6,250)†	1,900* (4,500)†	1,900* (††)†	1,900* (3,400)†	0* (2,450†
	2	3	0 (360)	0 (360)	0 (360)	0 (360)	0 (††)	0 (5,450)	0 (360)
2	1	1	1,800 (2,000)	1,650 (6,500)	1,821 (1,000)	1,780 (5,000)	1,780 (††)	1,760 (3,170)	0 (2,400)
	2	3	900 (2,600)	0 (3,240)	1,105 (1,000	910 (2,500)	910 (††)	910 (970)	860 (2,900)
	3	2	340 (950)	0 (886)	325 (580)	310 (735)	310 (††)	310 (100)	330 (1,100)
3	1	1	510 (1,040)	540 (1,880)	557 (715)	510 (1,860)	510 (††)	510 (1,820)	560 (1,050
	2	6	170 (1,380)	0 (350)	205 (1,114)	375 (350)	375 (††)	0 (350)	185 (1,200)
4	1	1	0 (3,400)	0 (7,400)	0 (3,400)	0 (7,400)	0 (††)	0 (10,400)	0 (3,400)
	2	3	0 (1,700)	0 (1,700)	0 (1,700)	0 (3,200)	0 (††)	0 (3,200)	0 (3,600)
5	1	1	715 (1,654)	0 (2,600)	685 (2,452)	685 (2,300)	685 (††)	0 (3,200)	0 (2,300)
	2	6	405 (1,409)	0 (2,000)	405 (1,560)	400 (1,500)	400 (††)	0 (2,022)	0 (1,484)
	3	5	300 (1,151)	0 (1,520)	302 (940)	300 (1,400)	300 (††)	0 (1,498)	0 (1,210)
6	1	4	730 (1,700)	820 (1,485)	783 (855)	775 (2,425)	775 (††)	775 (2,700)	700 (665)
7	1	1	0 (250)	430 (2,100)	0 (1,250)	0 (950)	0 (††)	0 (950)	485 (1,200)
	2	6	335 (740)	280 (970)	288 (370)	310 (1,000	310 (††)	310 (885)	290 (450)
	3	5	212 (635)	210 (830)	0 (870)	215 (830)	215 (††)	215 (770)	230 (630)
8	1	1	0 (310)	0 (300)	0 (1,600)	310 (300)	310 (††)	0 (300)	0 (1,700)
	2	6	0 (200)	156 (200)	0 (200)	200 (2,200	200 (††)	0 (2,100)	0 (200)
	3	5	0 (300)	0 (1,620)	0 (300)	0 (950)	0 (††)	0 (2,700)	0 (300)
9	1	6	0 (500)	0 (500)	0 (500)	0 (500)	0 (††)	0 (5,500)	0 (500)

* Production rates in bbls/day.
† Initial volumes in bbls.
†† Initial volumes are not known.

schedule. This probable discrepency is, however, made good when the levels in the tanks are initialized in the computer program on the basis of the actual levels.

In order to determine the average volume of interface created per barrel of products pumped, the pipeline company's schedules were analyzed by means of a computer program, written in Fortran IV. The program actually simulates the pumping of products into the pipeline and the resulting movements of products. The simulation is of next event type where the logic of simulation moves from event to event and the measure of performance of the system is taken after the completion of each event. The events, in this case, are pumpings and the measure of performance is the type of interface created. As the sequence of pumpings is already known, the main program does not have any logic segment which would make the decision as to which product to pump. The general flow chart of the computer program is given in Figure 2.1.

The main program reads in the pumping details, namely the station number, product code and volume pumped. It then scans the status of the pipeline and identifies the product type or constituent products of an interface present in front of the station from which a product is to be pumped. Consequently, it calls an appropriate subroutine which updates the status of the pipeline.

There are 5 different subroutines, namely, PSTAT0, PSTAT1, PSTAT3, PSTAT4 and PSTAT5, used for updating the status of the pipeline. The

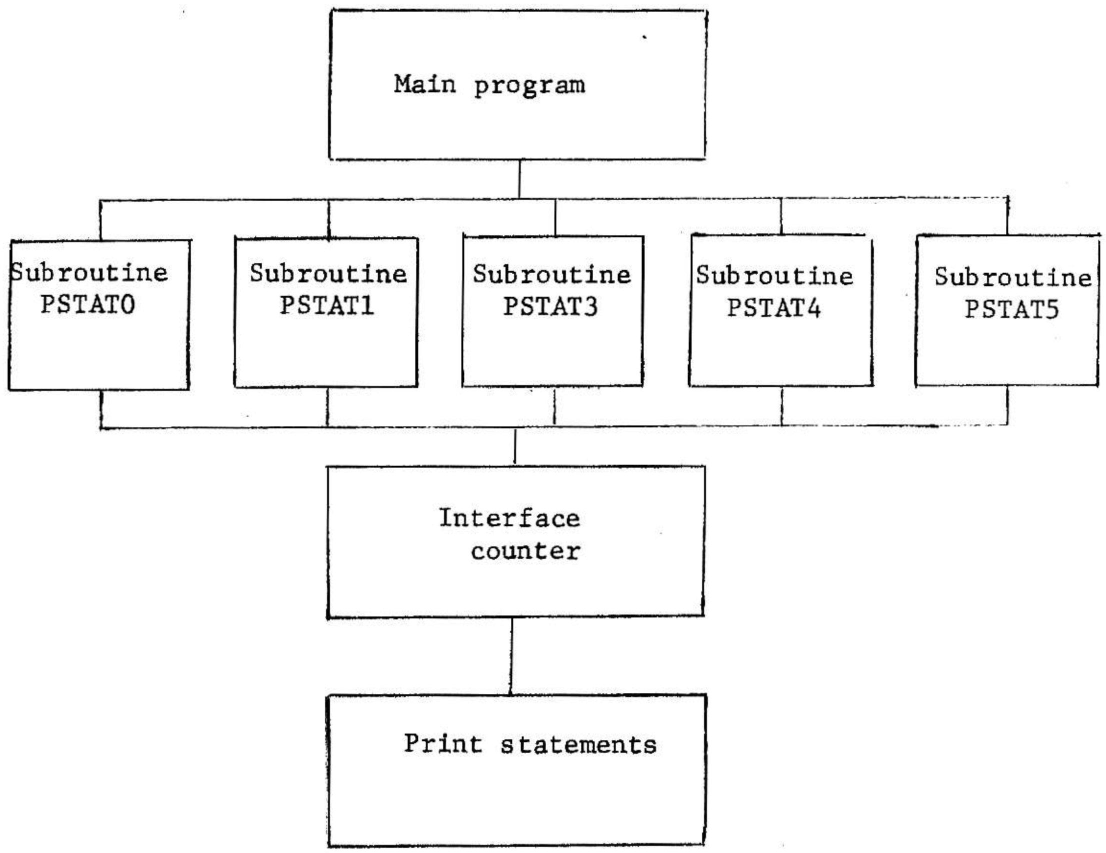


Fig. 2.1. General details of the program used for analyzing pipeline company's schedules.

structure of each subroutine is based on the type of interface created when pumping takes place. Although 8 different types of interfaces were identified in Chapter I, there are only 5 subroutines because, interfaces type 2 and 6 are merely sub-classes of type 1, and type 7 is a sub-class of type 0 interface. The procedure for updating the status of the pipeline in the case of the sub-classes is essentially the same as that of the main types of interfaces.

In each of these subroutines, a product in the pipeline is completely identified by a three dimensional vector, IP(I,J,K), where I,J and K represent pumping number, product sequence number, and an attribute of the product, respectively. The pumping number is found necessary in the identification of a product because, the exact location of some products, if not all products, will change after each pumping. The subscript K takes the values 1 through 6, each representing one particular attribute of the product. After the I-th pumping, the six attributes are:

IP(I,J,1)	code of the J-th product
IP(I,J,2)	starting co-ordinate of the J-th product
IP(I,J,3)	ending co-ordinate of the J-th product
IP(I,J,4)	code of the (J-1)-th product; IP(I,J-1,1) is the same as IP(I,J,4)
IP(I,J,5)	code of the (J+1)-th product; IP(I,J+1,1) is the same as IP(I,J,5)
IP(I,J,6)	volume of the J-th product

Although strictly speaking, the type codes of the (J-1)-th product and (J+1)-th product are not attributes of the Jth product, they were assumed to be so because such an assumption simplifys the updating procedure and in addition, serves the purpose of double checking the updated pipeline status. The print out of the pipeline status, however, is more meaningful if the variable NPARM in the main program has the value 1. The print out gives the sequence number, type code, beginning co-ordinate, end co-ordinate, and volume of each product. But if the value of NPARM is equal to 0 the pipeline status is printed out in a vector form.

The main program has the control after the pipeline status is updated. The interface counter incorporated, keeps a count of interfaces created. The schedule details are then printed out in tabular form if the value of NPARM is equal to 1. If NPARM is equal to 0, pumping details are printed out after each pumping. The value of variable JPARM is then checked; if it is equal to 0, then the pipeline status is printed out in vector form after every 5 pumpings and if it is equal to 1 pipeline status is printed out after each pumping in a vector form. At the end of a schedule, a summary of schedule details, which includes the total interface volume created, total volume pumped and the ratio of interface volume created per barrel of product pumped, is printed out.

Table 2.9 displays the summarized details of pipeline company's schedules. Appendices A, B and C give the list of variables used in the program, the flow charts, and the program itself, respectively.

In the seven production periods the total volume of products pumped is 218,999 bbls. The total volume of interface created is 18,200 bbls. There were totally 117 pumpings. The ratio of interface volume to total volume ranges from 5.49% to 16.13% with an average of 8.30%. All the schedules are stationary, there is only one schedule for each production period, and the average number of pumpings per day is 5.57.

Table 2.2

Details of Pipeline Company's Schedule No. 1

Pumping No.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Station No.	5	5	5	1	2	7	2	7	3	3	2	2	2	6
Product Type	NG	FB	K	K	K	NG	K	FB	FB	K	K	NB	IB	PB
Volume Pumped bbls	9000	1000	1300	5400	1161	682	1000	941	1326	1336	1564	3590	1429	2853

Table 2.3

Details of Pipeline Company's Schedule No. 2

Pumping No.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Station No.	5	5	5	2	2	2	7	2	1	7	1	7	6	3	2	8	4	2
Product Type	NG	FB	K	IB	NB	K	NG	K	K	FB	K	K	PB	K	K	FB	K	K
Volume Pumped bbls	1220	1600	2000	786	2790	1625	820	189	1221	1056	6159	2532	2556	2580	1138	1752	4000	7897

Table 2.4

Details of Pipeline Company's Schedule No. 3

Pumping No.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Station No.	5	5	5	1	7	1	2	7	2	7	3	3	6	2	2	2	8	2
Product Type	NG	FB	K	K	NG	K	K	FB	K	K	FB	K	PB	K	NB	IB	K	IB
Volume Pumped bbls	954	1624	2773	4537	720	1263	26	784	2199	1000	1331	1720	2503	3072	3882	513	1300	1004

Table 2.5

Details of Pipeline Company's Schedule No. 4

Pumping No.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Station No.	5	5	5	2	2	2	1	7	1	7	1	7	6	3	8	2	4	2	4
Product Type	NG	FB	K	IB	NB	K	K	NG	K	FB	K	K	PB	K	FB	K	NB	K	K
Volume Pumped bbls	1112	1147	1892	735	2468	1957	656	834	1129	1135	4045	700	3231	2381	2372	1481	1500	4598	4000

Table 2.6

Details of Pipeline Companys Schedule No. 5

	Pumping No.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Station No.	5	5	5	1	2	7	2	7	3	3	2	2	2	8	6
Production Type	NG	FB	K	K	K	NG	K	FB	FB	K	K	NB	IB	K	PB
Volume Pumped bbls	902	1198	2065	5252	445	661	1051	932	1270	1253	2409	3719	1335	1163	2630

Table 2.7

Details of Pipeline Company's Schedule No. 6

Pumping No.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Station No.	5	5	5	2	2	2	7	2	7	2	1	7	6	3	2	8	2	7	2	4
Product Type	NG	FB	K	IB	NB	K	NG	K	FB	K	K	K	PB	K	K	FB	K	FB	K	K
Volume Pumped bbls	1198	1622	2600	972	3196	422	754	1410	970	103	4527	700	3486	2314	480	1900	2909	5000	3568	1000

Table 2.8

Details of Pipeline Company's Schedule No. 7

Pumping No.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Station No.	5	5	5	1	2	2	7	2	2	7	3	3	3	8	6
Product Type	NG	FB	K	K	K	NB	NG	NB	IB	K	K	FB	K	K	PB
Volume Pumped bbls	910	1084	1700	2000	1650	2522	630	504	1252	1369	598	1133	695	1400	1155

Table 2.9

Summary of Pipeline Company's Schedules

Schedule No.	Total Volume Pumped bbls	Total Interface Volume Created bbls	Total Number of Interfaces Created	Total Number of Pumpings	Ratio of Interface Volume to Total Volume, %
1	24,482	2200	11.0	14	8.99
2	41,921	2300	11.5	17	5.49
3	31,205	3200	15.5	18	9.93
4	37,373	2200	11.0	19	5.89
5	26,285	2600	13.0	14	9.89
6	39,131	2700	13.5	20	6.90
7	18,602	3000	15.0	15	16.13
Total	218,999	18,200	90.5	117	

CHAPTER III

DEVELOPMENT OF A PIPELINE SCHEDULING ALGORITHM

In this chapter, a critical evaluation of the pipeline system is presented, with a view to formulate the basic scheduling rules to be embodied in the proposed algorithm. General, but sufficient details of the algorithm are then given and its application is demonstrated by generating a sample schedule. Finally, the step by step computational procedure of the algorithm is presented in a formal manner. As it can not be claimed that the algorithm can cope with a wide variety of production conditions at gas plants by generating only one schedule, it was further tested by incorporating it in a computer program, which simulated the production conditions and pumpings for six consecutive periods. The computational procedure and results will be discussed in Chapter IV.

3.1 Basic Concepts

The basic objectives of the proposed pipeline scheduling algorithm are: (1) to systematize the procedure for selecting the products to be pumped, and (2) to minimize the volume of interface created per barrel of products pumped. In the existing method of scheduling, the pumping sequence worked out by the scheduler, involves a great deal of hand calculations and a good amount of judgement based on his experience. If the computer program used to test the feasibility of this sequence reports an infeasibility, a new sequence has to be tried. Sometimes this process may be repeated a few times until a feasible schedule is obtained. Moreover, the computer program has no provisions to identify and keep a count of interfaces and consequently, the measure of performance, which is the ratio of total interface volume created to the total volume of products pumped, is never evaluated. Therefore, it is obvious that a systematized procedure, capable of generating schedules based on certain dispatching rules, and evaluating the measure of performance of generated schedules, is of great importance to the pipeline company. The interfaces, as stated earlier, represent a loss of revenue, and, therefore, their total volume should be as small as possible. In addition, a schedule which creates a small number of interfaces leads to having large volumes of each product in the pipeline at any time and this reduces the number of times tests have to be conducted by the personnel at the delivery point, to identify each product and interface before being diverted to suitable storage locations.

An examination of Figure 1.1 shows that the product K is produced at all gas plants except at the plants attached to pump stations 6 and 9. Table 2.2 through 2.8 show that this product is produced most often at all plants and at relatively higher rates than other products. These facts lead to a conclusion that it may never be necessary to pump this product into any other product and create additional interfaces. However, products IB, FB, NG, and PB at stations 2, 3, 5, and 6, respectively, will create interfaces of type 1 with 400 bbls of degraded product whenever they are pumped, because of the fact that there are no plants, upstream to these plants, which produce the same products. Naturally, the more often these products are pumped in a given period of time, the more will be the volume of interfaces created. However, if these products are pumped only when their volumes reach their safe maximum volumes in their tanks, few interfaces will be created during the same period of time.

All the other products in the system can be pumped, at least theoretically, into similar products without the risk of creating interfaces. However, a careful analysis of disposition of pump station 7 on the pipeline would reveal that it would very rarely be possible to pump products FB and NG at these stations into similar products. The FB storage tank in this station has a small net capacity of 1400 bbls and in relation to its capacity, it has a fairly high average input rate. It is, therefore, very likely that this product will reach its safe maximum level much earlier than a similar product pumped from station 5, could reach the discharge point of station 7 in the pipeline. Similarly, it would hardly be possible to pump product NG at this station into a similar product pumped from station 5.

Now consider the pump station 2 which has storage tanks for three different products. It can be safely assumed that product K, can always be scheduled such that it is pumped into a similar product, especially due to the fact that the product NB at station 1 is not produced during all the six production periods under consideration. However, product IB at this station, as mentioned earlier, can never be pumped into a similar product and therefore, it should always be pumped when its volume in the tank reaches the safe maximum volume. Product NB at this station should also be pumped under overflow condition (for convenience, if the volume of a product in its tank reaches safe maximum volume, the product is said to be under overflow condition). However, if we recall the various types of interfaces that can be created, the type 2 interface with only 200 bbls of degraded product is formed whenever a product is pumped immediately behind some other products from the same station which created a type 1 interface. Therefore, if product NB is pumped, regardless of its volume in the tank, immediately behind IB, it will create only 200 bbls of degraded product each time instead of 400 bbls. This means that, when either of these two products is pumped under overflow condition, the other product should be given priority for the next pumping.

Similarly, stations 5, 7, and 8 also store three different products, namely K, FB, and NG. It should be possible to schedule the product K always without causing additional interfaces, but the same argument can not be applied to products FB and NG. Therefore, these products should be pumped into similar products if possible, and if either one of them is pumped under overflow condition the other product from the same station should be given priority for the next pumping.

The procedure for giving priority to some products, discussed so far, can be generalized and expressed mathematically as follows: If a product i, in tank j, at station k is pumped under overflow condition during the n-th pumping as indicated by a pumping condition index, β^{n}_{ijk} being equal to 1, the other product (excluding product k) at the same station is given priority to the n+1-th pumping by setting a priority index , α_{ijk}^{n+1} equal to 1, where $i \neq 1$.

The product PB, stored only at station 6, requires special attention because, when it flows through the pipeline, it should always be followed and preceded by product K. As this product can never be pumped into a similar product, the imposed restriction can be satisfied only by pumping it into product K. But if it is pumped whenever product K approaches station 6, too many interfaces will be created; on the other hand, if it is pumped only when it is about to overflow, there may not be product K in the pipeline at that time. Therefore, it becomes necessary to determine an optimum volume of product PB, such that when this volume is pumped, the resulting frequency of pumping is low and the imposed condition is always satisfied. As there is no way to estimate the optimum volume mathematically, a trial simulation program was run with various possible optimum volumes. It was found that there is no unique optimum volume, and that during the time the volume of PB in its tank exceeds 90% and reaches 100% of the maximum safe volume, it is possible to pump it, satisfying the imposed restriction.

The proposed algorithm is event-oriented, where an event is either pumping a product or the pipeline remaining idle for a known length of time. It considers the entire production period to generate a feasible schedule. The time, t is first initialized as 0 and then incremented after each pumping or idle period. Each product is represented by three indices; i,j and k, where i is the type code of the product, j is the tank number, and k is the station number at which the tank is situated. At any time t, the overflow time of each product, T_{ijk} is compared with t itself, and if any T_{ijk} is equal to t, an overflow condition exists and it is necessary to pump that particular product immediately.

The duration of pumping, T^n_{ijk}, is then calculated such that

$$T^n_{ijk} = [P_{ijk}(t) - (L_{ijk} + 5.0)] \ / \ H_{ijk}(t) \, ,$$

where P_{ijk} and L_{ijk} are the present and minimum safe volumes of the product under overflow condition, and $H_{ijk}(t)$ is the rate of reduction of the volume of this product in its tank when the pumping takes place. $H_{ijk}(t)$ is calculated such that

$$H_{ijk}(t) = G_{ijk} - F_{ijk}(t)$$

where G_{ijk} and F_{ijk} are the pumping rate and input rate of product under consideration. Note that while calculating the pumping duration, 5 bbls. of the product is always left above the safe minimum volume. The next earliest overflow time, T* is then compared with the sum of present time and pumping duration, $t + T^n_{ijk}$. If T* is less than $t + T^n_{ijk}$, some product will reach overflow condition, if the already selected product is pumped for the entire calculated pumping duration. T^n_{ijk} should therefore, be modified such that

$$T^n_{ijk} = T^* - t.$$

If no product is at overflow condition at time t, the earliest overflow time T* will be greater than t. The priority indices of all products, α^n_{ijk} are then checked. A product having $\alpha^n_{ijk} = 1$ is selected, and the duration of pumping is calculated in a way similar to that described for a product at overflow condition. If no product has priority, the status of the pipeline in front of station 6 and the volume of product PB in its tank at this station are checked. Product PB is selected for pumping if; (1) $P_{416} \geq 0.9\ U_{416}$, where U_{416} is the maximum safe volume of product PB; and (2) there is product K in the pipeline in front of station 6. If both conditions are not satisfied, product PB is not considered as a candidate product for pumping. The entire pipeline status is then checked to identify those products, at the pump stations, which if pumped would not create additional interfaces. The volumes of the products which are available for pumping, are designated as $v_{ijk}(t)$ and computed such that

$$v_{ijk}(t) = P_{ijk}(t) - L_{ijk}$$

The product which has the maximum available volume is then selected for pumping.

All the pumping times calculated, except those calculated for products under overflow condition, are compared with minimum allowable pumping time, τ. If T^{n}_{pqr} is less than τ, the product selected is not pumped. It is necessary to wait till the product level builds up to sufficient level and, therefore, the waiting time or the idle period of the pipeline, W is calculated such that

$$W = G_{ijk} \cdot \tau / F_{ijk}(t) .$$

The time t is then incremented to t + W and the status of all tanks is updated and the selection procedure is started all over again. Note that in order to avoid an infeasibility, W should be modified as T* - t if t + W is greater than T*.

If T^n_{ijk} is equal to or greater than τ, the volume of the product that can be pumped, V_{ijk} is computed such that

$$V^n_{ijk} = G_{ijk} \cdot T^n_{ijk}$$

and the actual pumping is simulated by moving the products present in the segment of pipeline downstream to the pump station k, by an amount equal to V^n_{ijk}. The type of interface created is identified and the status of all tanks is updated. The time t, is also updated as $t + T^n_{pqr}$ and the selection procedure is continued until the end of the production period. At the end of each schedule period the measure of performance is evaluated by computing the ratio of total interface volume created to the total volume of products pumped. Figure 3.1 displays the general structure of the algorithm.

The following notation are used in the proposed algorithm:

i	product index, i = 1, 2, ..., I.
j	tank index, j = 1, 2, ..., J_k.
k	pump station index, k = 1, 2, ..., K.
n	pumping number during a schedule period, n = 1, 2, ..., N.
I	total types of products produced in the system.
J_k	total number of tanks at station k.
K	total number of pump stations in the system.
N	total number of pumpings carried out during a schedule period.

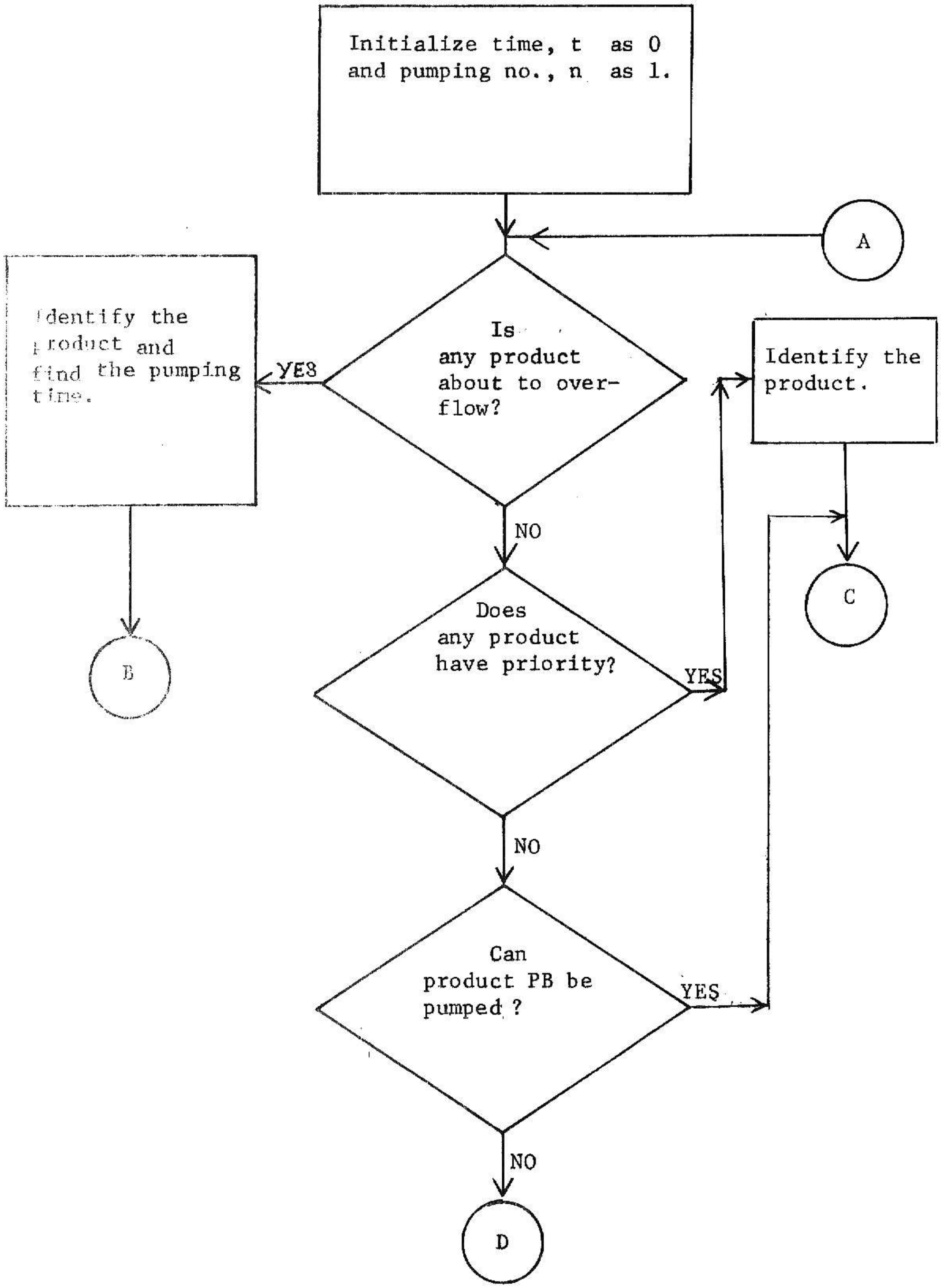


Fig. 3.1. General Details of the Proposed Algorithm

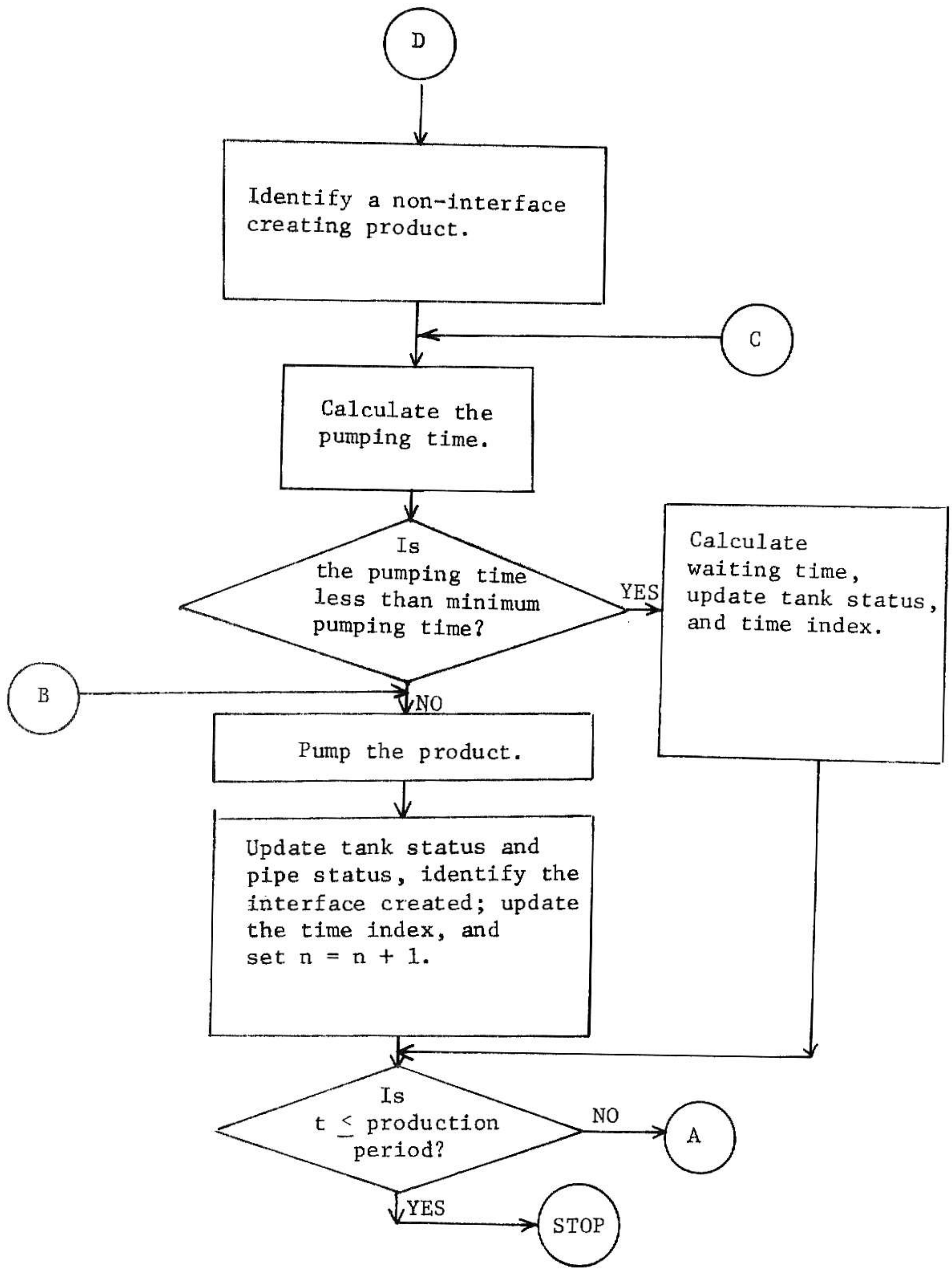


Fig. 3.1. General Details of Proposed Algorithm (continued)

T^n_{ijk} length of time in which product i is pumped from tank j at station k during the n-th pumping, for all i,j,k.

τ minimum allowable pumping time, for all products, in all tanks and at all stations.

W idle period of the pipeline.

$F_{ijk}(t)$ input rate per hour, for product i, in tank j, at station k, at time t, for all i,j,k.

G_{ijk} pumping rate per hour, of product i, in tank j, at station k, for all i,j,k.

$H_{ijk}(t)$ reduction rate of volume per hour, when product i, in tank j, at station k, at time t is pumped, such that

$$H_{ijk}(t) = G_{ijk} - F_{ijk}(t)$$

$P_{ijk}(t)$ volume of product i, present in tank j, at station k, at time t, for all i,j,k.

U_{ijk} maximum safe volume of product i, in tank j, at station k.

L_{ijk} minimum safe volume of product i, in tank j, at station k.

V^n_{ijk} volume of product i pumped from tank j, at station k, during the n-th pumping such that

$$V^n_{ijk} = G_{ijk}(t) \cdot T^n_{ijk} .$$

$v_{ijk}(t)$ volume of product i, in tank j, at station k, available for pumping at time t such that

$$V_{ijk}(t) = P_{ijk}(t) - L_{ijk}$$

m product index in the pipeline, $m = 1, 2, \ldots, M(t)$

$M(t)$ total number of products present in the pipeline at time t.

$B_m(t)$ starting point, in terms of barrels, of product m in the pipeline at time t.

$E_m(t)$ ending point, in terms of barrels, of product m in the pipeline at time t.

C_k location, in terms of barrels, of station k.

T_{ijk} time at which product i in tank j, at station k reaches its safe maximum level, U_{ijk}.

$X_m(t)$ type of product m in the pipeline.

$\hat{k}_n$ station number, from which a product is pumped during the n-th pumping.

α^n_{ijk} priority index for product i, in tank j, at station k during the n-th pumping, i,j $\neq$ 1.

$\alpha^n_{ijk} = 1$ indicates that during the n-th pumping, product i in tank j, at station k is given priority.

$\alpha^n_{ijk} = 0$ indicates that during the n-th pumping product i, in tank j, at station k has no priority.

β^n_{ijk} index to indicate under what condition product i, from tank j, at station k was pumped during the n-th pumping.

$\beta^n_{ijk} = 1$ indicates that product i, from tank j, at station k was pumped, during the n-th pumping, when it had reached its safe maximum level, U_{ijk}.

$\beta^n_{ijk} = 0$ indicates that product i from tank j at station k was pumped, during the n-th pumping under normal conditions that is, at the time of pumping

$P_{ijk}(t) < U_{ijk}$.

R_s time for which production levels remain the same for a given schedule.

3.2 Sample schedule.

The use of the algorithm is illustrated by generating a schedule for the first production period. The initial volumes and production and pumping rates of all products are given in Table 3.1. The minimum allowable pumping time τ is assumed to be 30 minutes. For convenience, let each product be represented by enclosing its three indices in paranthesis. For example (1,2,3) will represent product 1 stored in storage tank 2, at pump station 3.

Step 1. Initialize the schedule by setting the time, t = 0 and the pumping number, n = 1.

Step 2. Find the overflow time, T_{ijk} of all products. For example, the overflow time of product (1,1,1) is

$$T_{111} = [(U_{111} - P_{111}(t)) / F_{111}(t)]$$

$$= (6800.0 - 4429.0) / (1950.0 / 24.0)$$

$$= 29.18 \text{ Hours.}$$

Similarly, overflow times are calculated for all the other products and entered in column 10 of Table 3.1. For products which are not produced in this period, the production rate per hour, $F_{ijk}(t)$ is 0 and the overflow times of these products is ∞. The earliest overflow time, T^* is the minimum of all overflow times. T^* is therefore, 29.18 hours. Now, if an overflow condition exists, identify the product which is about to overflow. Since $T^* > t$, or $29.18 > 0$, the overflow condition does not exist and there is no need to pump product (1,1,1), which has the earliest overflow time, at this time.

Step 3. Check if any product has a priority. Since the priority index, $\alpha^1_{ijk} = 0$ for all i,j and k, no product has a priority at this stage.

Step 4. Check for any imposed conditions on the products. As mentioned earlier, only PB produced solely at station 6, has an imposed condition that it should be followed and preceded in the pipeline by product K. From Figure 3.2, the location of station 6, C_6, starting and ending location of the first product in the pipeline, $B_1(t)$ and $E_1(t)$, are found to be 19,504, 0, and 20,404, respectively. Since $B_1(t) < C_6 < E_1(t)$, the first product in the pipeline is in front of station 6. The type code of this product, $X_1(t)$, is 1, see Figure 3.2. Check $P_{416}(t)$, the volume of product PB in its storage tank. Column 6 in Table 3.1 shows that $P_{416}(t)$ is 1,700 bbls. As $P_{416}(t) < 0.9 \cdot U_{416}$, or, $1700 < 0.9 \cdot 3600.0$ product (4,1,6) need not be pumped now.

Step 5. Identify now those products which, if pumped, would not create additional interfaces. Set the station index, k equal to 1. As stated earlier, the first product in the pipeline, with code 1, has its starting location, $B_1(t) = 0$ and ending location, $E_1(t) = 20,404$. In checking the type codes of the products stored at station 1, it is found that the product with code 1 is of them and its available volume, v_{111}, is 3979 bbls. By proceeding from station to station, incrementing k by one, at a time, the products which can be pumped now without the risk of causing additional interfaces and their available volumes are:

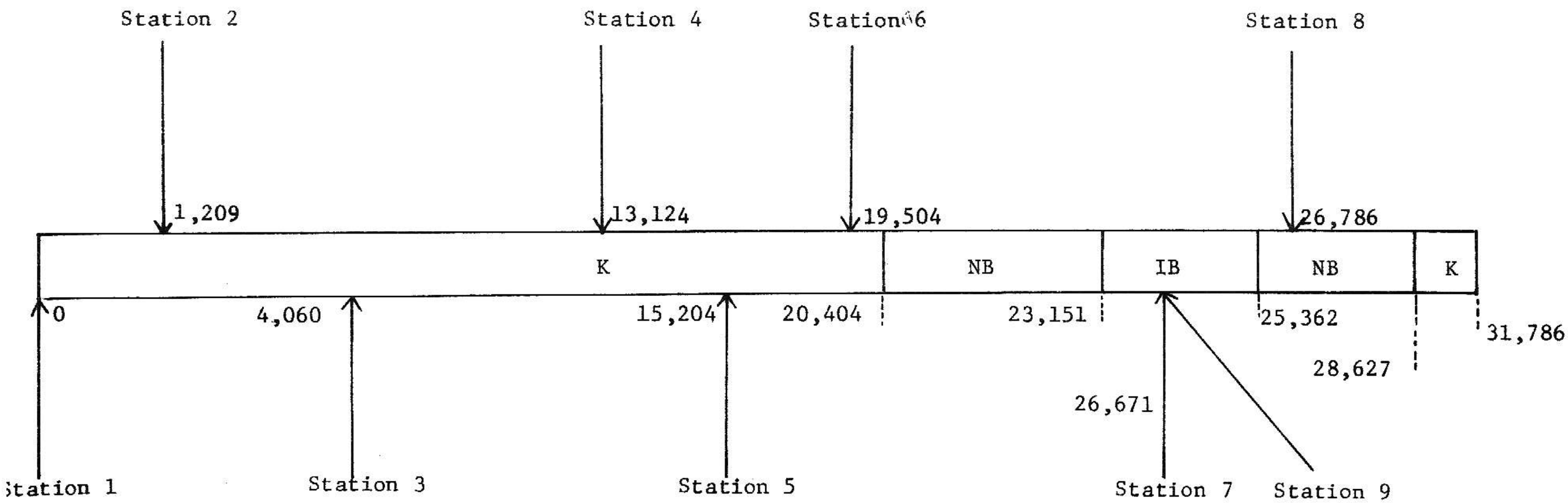


Fig. 3.2. Pipe Status Before First Pumping.

Product	Available Volume (bbls)
(i,j,k)	$v_{ijk}(t)$
(1,1,1)	3979.0
(1,1,2)	1250.0
(1,1,3)	690.0
(1,1,5)	1054.0

The available volumes of all other products are 0. The maximum available volume, $v^*_{ijk}(t)$, is 3,979.0 barrels and therefore, product (1,1,1) is chosen for pumping. Set $\beta^1_{111} = 0$.

Step 6. Compute the time required to pump this product, T^1_{111} such that

$$T^1_{111} = [(P_{pqr}(t) - (L_{pqr} + 5.0)] / H_{pqr}(t)$$

$$= (4429.0 - 455.0) / 398.80$$

$$= 9.97 \text{ Hours.}$$

Since $t + T^1 < T^*$, or, $(0 + 9.98) < 29.18$, no product will over flow when this product is being pumped.

Step 7. Check if the pumping time is greater than minimum allowable pumping time, τ. This check is necessary because $\beta^1_{111} = 0$. Since pumping duration, $T^1_{111} > \tau$ or $9.98 > 0.5$, the pumping will be carried out. The volume of the product that will be pumped, V^1_{111} is found such that

$$V^1_{111} = T^n_{111} \cdot G_{111}(t)$$

$$= 9.97\ (480)$$

$$= 4783 \text{ bbls.}$$

Set the index of the station from which the product is pumped during the n-th pumping, $\hat{k}_n = 1$.

Step 8. Update the present time, t such that

$$t = 0 + 9.97$$

$$= 9.97 \text{ Hours.}$$

The volume of the product (1, 1, 1) in its tank at the end of the pumping is

$$P_{111}(t) = P_{111}(t - T^1_{111}) - V^1_{111} + F_{111}(t) \cdot T^1_{111}$$

$$= 4{,}429 - 4{,}783 + 81.2\ (9.97)$$

$$= 455.6 \text{ bbls.}$$

Enter this in column 11 of Table 3.1. Note that, for convenience the actual volume entered has been modified as 455 bbls.

Update the overflow time of this product by computing T_{111} such that

$$T_{111} = t + [(U_{111} - P_{111}(t)) \ / \ F_{111}(t)]$$

$$= 9.97 + (6{,}800 - 455.6) \ / \ 81.2$$

$$= 89.77 \text{ Hours.}$$

and enter this in column 10 of Table 3.1.

Step 9. Compute the interface created. As the code of the first product in the pipeline and the product which is pumped into it

Table 3.1

Tank Status During Schedule Period 1

Station No.	Tank No.	Product type code	Maximum safe volume bbls	Minimum safe volume bbls	Volume at the beginning of first production period bbls	Production rate bbls/Hour	Pumping rate bbls/Hour	Rate of volume reduction in tank during pumping bbls/Hour	Overflow time Hours	Volume in tanks after pumping bbls: After first pumping	After second pumping	...	After N-th pumping
k	j	i	U_{ijk}	L_{ijk}	P_{ijk}	$F_{ijk}(t)$	G_{ijk}	$H_{ijk}(t)$	T_{ijk}	$P_{ijk}(t)$	$P_{ijk}(t)$		$P_{ijk}(t)$
1	2	3	4	5	6	7	8	9	10	11	12	...	10+N
1	1	1	6,800	450	4,429	81.2	480	398.8	89.77*	455			
	2	3	3,600	360	360	0	480	480.0	∞	360			
2	1	1	7,300	750	2,000	75.0	625	550.0	70.67	2,750			
	2	3	4,500	450	2,600	37.5	625	587.5	50.67	2,975			
	3	2	1,800	100	950	14.2	625	610.8	60.00	1,092			
3	1	1	3,300	350	1,040	21.2	650	628.8	106.35	1,252			
	2	6	1,600	250	1,380	7.1	650	642.9	31.06	1,451			
4	1	1	32,000	3,400	3,400	0	650	650.0	∞	3,400			
	2	3	17,000	1,700	1,700	0	650	650.0	∞	1,700			
5	1	1	5,000	600	1,654	29.0	600	571.0	112.31	1,944			
	2	6	3,000	400	1,409	16.8	600	583.2	94.28	1,577			
	3	5	2,300	300	1,151	12.5	600	587.5	91.92	1,276			
6	1	4	3,600	360	1,700	30.4	650	619.6	62.47	2,004			
7	1	1	2,050	250	250	0	550	550.0	∞	250			
	2	6	1,555	150	740	13.9	550	536.1	58.0	879			
	3	5	1,700	150	635	8.85	550	541.2	120.0	724			
8	1	1	4,200	300	300	0	490	490.0	∞	300			
	2	6	6,000	200	200	0	490	490.0	∞	200			
	3	5	4,500	100	100	0	490	490.0	∞	100			
9	1	6	5,500	500	500	0	480	480.0	∞	500			

* The initial overflow time was 29.18 hours.

are the same, or $X_1(t) = p$, and also as the station from which the product is pumped, denoted by $\hat{k}_1$, is equal to 1, type 0 interface is created.

Step 10. Update the pipe status by moving all the products downstream by an amount equal to 4,783 barrels. This is accomplished by adding 4,783 to $E_1(t)$ and the same amount to $B_m(t)$ and $E_m(t)$, $m = 2,3,4,5$. Figure 3.3 displays the updated pipeline status.

Step 11. Check if the schedule period has exceeded production period. As $t < R_s$ or $9.98 < 96.0$, set $n = 2$ and go to Step 2.2 to find the next product to be pumped. The procedure is continued until the time t is equal to the production period.

3.3 Computational Algorithm.

Now that the basic concepts and a sample schedule have been discussed, a formal step by step algorithm is presented below.

Step 1: Initialize the schedule by setting the time, $t = 0$, and the pumping number, $n = 1$.

Step 2: Determine the earliest overflow time and identify the product, if overflow condition exists.

2.1 Compute the overflow time, T_{ijk}, such that

$$T_{ijk} = [(U_{ijk} - P_{ijk}(t)) / F_{ijk}(t)]$$

2.2 Find the earliest over flow time, T*, such that

$$T^* = \min_{i,j,k} [T_{ijk}]$$

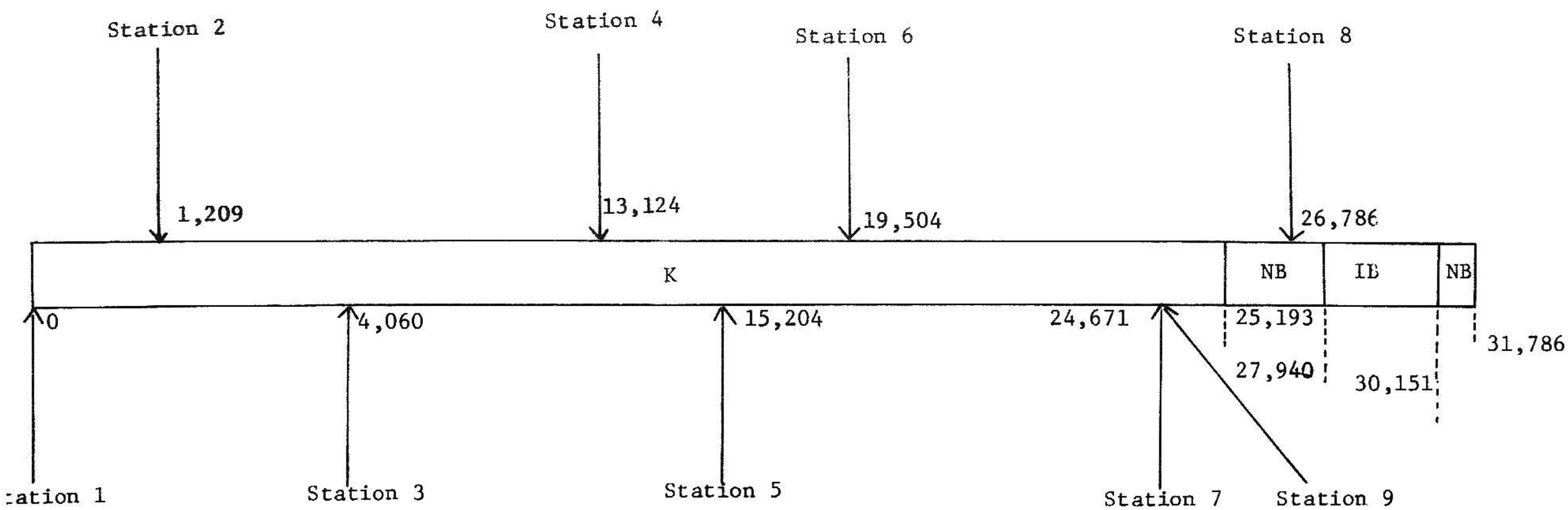


Fig. 3.3 Pipe Status After the First Pumping

2.2.1 If $T^* = t$, find the next earliest overflow time and designate it as T^*. The indices (i,j,k) of the product which is at overflow condition are replaced by (p,q,r). Set $\beta^n_{pqr} = 1$, and $\alpha^{n+1}_{ijr} = 1$ where $i \neq 1$ and p, $j \neq q$. Go to Step 6.

2.2.2 If $T^* > t$, go to Step 3.

Step 3: Identify the product which has a priority.

3.1 If $\alpha^n_{ijk} = 1$, set $i = p$, $j = q$, $k = r$, $\beta^n_{pqr} = 0$ and $\alpha^{n+1}_{pqr} = 0$ and go to Step 6.

3.2 If $\alpha^n_{ijk} = 0$, go to Step 4.

Step 4: Check for any imposed condition, such as fixed successor and/or predecessor for any product. Only product (4,1,6) has an imposed condition that it should always be preceded and followed in the pipeline by a product having type code 1.

4.1 Identify the product m in the pipeline which satisfies the following relations.

$$B_m(t) < C_6 \text{ and } E_m(t) > C_6$$

If there is no such product, go to Step 5.

4.2 Check $P_{416}(t)$ and $X_m(t)$

4.2.1 If $P_{416}(t) \geq 0.9\ U_{416}$ and $X_m(t) = 1$, set $p = 4$, $q = 1$, $r = 6$, $\beta^n_{416} = 0$ and go to Step 6.

4.2.2 If either $P_{416} < 0.9\ U_{416}$ or $X_m \neq 1$ go to Step 5.

Step 5: Identify the products which if pumped will not create additional interfaces.

5.1 Set the station index $k = 1$.

5.2 Check whether there is a product or an interface in the pipe in front of station k

5.2.1 If $B_m(t) < C$ and $E_m(t) > C_k$, for any m, $m = 1, 2, \ldots, M(t)$, a product is present. Check the product index, i associated with each tank j at station k.

- If any $i = X_m(t)$, and $k = 1$, find the available volume, $v_{ijk}(t)$, such that

$$v_{ijk}(t) = P_{ijk}(t) - L_{ijk} \text{ and go to Step 5.3}$$

- If any $i = X_m(t)$, $k \neq 1$, and both $B_m(t) \leq C_k - 200$ and $E_m(t) \geq C_k + 200$, find the available volume $v_{ijk}(t)$ such that $v_{ijk}(t) = P_{ijk}(t) - L_{ijk}$ and go to Step 5.3.
- If any $i = X_m(t)$, $k \neq 1$ and either $B_m(t) > C_k - 200$ or $E_m(t) < C_k + 200$, set $v_{ijk}(t) = 0$ to avoid type 7 interface and go to Step 5.3.
- If $i \neq X_m(t)$, set $v_{ijk}(t) = 0$ and go to Step 5.3.

5.2.2 If either $B_m(t) < C_k$ and $E_m(t) = C_k$, or $B_m(t) = C_k$ and $E_m(t) > C_k$, an interface is present in the pipeline. Set $v_{ijk}(t) = 0$

5.3 Set $k = k+1$ and check k.

5.3.1 If $k > K$, find the maximum available volume,

$$v^*_{ijk}(t) = \max_{ijk} [v_{ijk}(t)]$$

and check $v^*_{ijk}(t)$.

- If $v^*_{ijk}(t) = 0$, set the waiting time, W equal to T*-t, and go to Step 7.2.4.
- If $v^*_{ijk}(t) \neq 0$, set i = p, j = q, k = r, $\beta_{pqr} = 0$ and $\alpha^{n+1}_{ijr} = 0$ where $i \neq p$ and $j \neq q$ and go to Step 6.

5.3.2 If $k \leq K$ go to Step 5.2.

Step 6: Compute the pumping time, T^n_{pqr}.

6.1 Find T^n_{pqr} such that

$$T^n_{pqr} = [P_{pqr}(t) - (L_{pqr} + 5.0)] / H_{pqr}(t)$$

6.2 Set $T^n_{pqr} = T^* - t$, if $t + T^n_{pqr} > T^*$

Step 7: Check if the pumping can be carried out. If it is not, compute the waiting time and update the tank status.

7.1 If $\beta^n_{pqr} = 1$, compute the volume to be pumped, V^n_{pqr} such that

$$V^n_{pqr} = T^n_{pqr} \cdot G_{pqr}(t).$$ Set $\hat{k}_n = r$ and go to Step 8.

7.2 If $\beta^n_{pqr} = 0$ and $T^n_{pqr} < \tau$, check $F_{pqr}(t)$.

7.2.1 If $F_{pqr}(t) = 0$, the product (p,q,r) can not be pumped during this schedule. Set the available volume of this product, $v_{pqr}(t)$ equal to 0 and go to step 5.3.1, so that one of the other candidate products can be selected.

7.2.2 If $F_{pqr}(t) \neq 0$, find the waiting time, W such that

$$W = (G_{pqr} \cdot \tau) / F_{pqr}(t)$$

7.2.3 Set $W = T^{*}-t$ if $t + W > T^{*}$

7.2.4 Set $t = t + W$ and update the volume of products in all tanks such that

$$P_{ijk}(t) = P_{ijk}(t - W) + F_{ijk}(t) \cdot W,$$

and go to Step 11.

7.3 If $\beta^{n}_{pqr} = 0$ and $T^{n}_{pqr} \geq \tau$, compute the volume to be pumped, V^{n}_{pqr} such that

$$V^{n}_{pqr} = T^{n}_{pqr} \cdot G_{pqr}(t).$$

Set $\hat{k}_{n} = r$ and go to Step 8.

Step 8. Update the volume of products in all tanks and overflow time of the product already pumped.

8.1 Set $t = t + T^{n}_{pqr}$

8.2 Compute $P_{pqr}(t)$ for the product which was pumped such that

$$P_{pqr}(t) = P_{pqr}(t-T^{n}_{pqr}) - V^{n}_{pqr} + F_{pqr}(t) \cdot T^{n}_{pqr}$$

8.3 Compute the new overflow time, T_{pqr} such that

$$T_{pqr} = t + (U_{pqr} - P_{pqr}(t)) / F_{pqr}(t)$$

8.4 Update the volumes in all the other tanks such that

$$P_{ijk}(t) = P_{ijk}(t - T^{n}_{pqr}) + F_{ijk} \cdot T^{n}_{pqr},$$

$i \neq p$, $j \neq q$ and $k \neq r$.

8.5 Update pumping number, n such that $n = n + 1$

Step 9. Compute the interface created.

9.1 If $B_{m}(t) < C_{r}$ and $E_{m}(t) < C_{r}$, for any m, $m = 1,2,\ldots,M(t)$, a product is present in the pipeline in front of station r. Check $X_{m}(t)$.

9.1.1 If $X_m(t) = p$ check $B_m(t)$, $E_m(t)$, and $\hat{k}_n$

- If $\hat{k}_n = 1$, designate the interface created as type 0 and go to Step 10.
- If $B_m(t) > C_r - 200$, or $E_m(t) < C_r + 200$, designate the interface created as type 7 and go to Step 10.
- If both $B_m(t) < C_r - 200$ and $E_m(t) > C_r + 200$ designate the interface created as type 0 and go to Step 10.

9.1.2 If $X_m(t) \neq p$, check $\hat{k}_n$.

- If $\hat{k}_n = 1$, designate the interface created as type 6 and go to Step 10.
- If $\hat{k}_n \neq 1$, designate the interface created as type 1 and go to Step 10.

9.2 If either $B_m(t) = C_r$ and $E_m(t) > C_r$, or $B_m(t) < C_r$ and $E_m(t) = C_r$, an interface is present in the pipeline in front of station r. Check $X_m(t)$ and $X_{m+1}(t)$

9.2.1 If $X_m(t) = p$, designate the interface created as type 3 and go to Step 10.

9.2.2 If $X_{m+1}(t) = p$, designate the interface created as type 4 and go to Step 10.

9.2.3 If both $X_m(t) \neq p$ and $X_{m+1}(t) \neq p$, check $\hat{k}_{n-1}$, $\hat{k}_{n-2}$, till $\hat{k}_n = r$.

- If all $\hat{k}_n > r$, designate the interface created as type 2 and go to Step 10.

- If any $\hat{k}_n < r$, designate the interface created as type 5 and go to Step 10.

Step 10. Update the pipeline status.

Starting at station r, move each product downstream by a distance equal to V^n_{pqr}, until the delivery point is reached.

Step 11. Check for the end of schedule.

1.1 If $t < R_s$ go to Step 2.2

1.2 If $t \geq R_s$ the schedule during the fixed production period is obtained.

CHAPTER IV

COMPUTATIONAL PROCEDURE AND RESULTS

The proposed algorithm developed in Chapter III was programmed in FORTRAN IV. The program consists of a main routine and five subroutines. The subroutines are used to update the pipeline status after each pumping, and they have already been discussed in Chapter II. Figure 3.1, which illustrates the broad details of the algorithm also serves to illustrate the general details of the program. The detailed flow chart is given in Appendix E and the program itself, with a specimen output is given in Appendix F. In this chapter, a description of the main program is given and the results obtained are analyzed.

4.1 Computer Program Description:

The function of the main program is to (1) determine the type of product to be pumped; (2) to update the storage tanks and pipeline status; (3) to count the number of interfaces created during each schedule period; and (4) to summarize the schedule generated in the form of a table so that the operators at the pump stations can understand the schedule details easily. The data read in by the program is divided into two groups, namely, fixed data and varying data. The fixed data comprises location of pump stations, termination point of pipeline, type of products stored in each pump station, maximum and minimum safe volumes of all tanks and pumping rates of all pumps. These details are classified as fixed because they are not changed from schedule to schedule. The varying data comprises pipeline status, initial volumes of products in all tanks, production period, and production rates at all gas plants. These are classified as varying because it is assumed that when the program is put to use, only one schedule will be generated at a time, and that the pipeline status and tank status (based on actual volumes), will be initialized before each schedule is generated. In the program, the termination point of the pipeline or the delivery point is assumed to be 31,786 bbls or 5,000 bbls downstream of the last pump station, namely station 8. In reality, however, it extends up to 65,936 bbls. This was done because the products in the pipeline, after the last pumping station, just move after each pumping without any additional interfaces and, therefore, termination of the pipeline at any point after the last pump station does not affect the characteristics of the pipeline system. However, if it is required to know when the product and interfaces arrive at the actual termination point, the variable LIMIT which represents the termination point should be given a value of, say, 70,936 bbls which actually has an imaginary length of 5000 bbls more than the true length.

While the general structure of the program is the same as that of the algorithm, it has a few additional steps, mainly for the purpose of reporting any infeasible conditions. As the algorithm is constructed in such a way that the system is always feasible, it may seem that these steps are superfluous; but they serve as precautionary measures against feeding in wrong data pertaining to initial volumes of products in all storage tanks. Also, though the possibility of two tanks overflowing at precisely the same time is remote, the program checks and reports the possibility of such an event and then terminates further execution. This situation can be dealt with by pumping one of the products much earlier than the overflow time, say, right at the beginning of the schedule. In this instance, it will be necessary to resort to hand calculations. The remaining pumpings in the schedule can then be generated by suitably initializing time, storage tanks and pipeline status.

The summary of the schedule printed out at the end of each schedule gives such details as total volume of interface created during the schedule, total volume of products pumped and the ratio of interface volume to total volume of products pumped. The type of output obtained, as in the case of the program used to analyze pipeline company's schedules discussed in Chapter II, depends upon the values of variables NPARM and JPARM. If at any time, some schedule details or pipeline status is suspected to be erroneous, the values of NPARM and JPARM should be set equal to 0 and 1, respectively. The resulting output is so comprehensive that the error conditions can be easily traced.

4.2 Computational Results:

A summary of the computational results is displayed in Table 4.1. Note that periods 4 and 5 are combined together to form one period, since both periods are identical. The program was run for seven different minimum pumping times ranging from 20 minutes to 60 minutes. Due to the nature of the algorithm incorporated to make decisions as to which products to pump, all the schedules are non-stationary. As might be expected, the number of pumpings during each schedule decreases,

Table 4.1

Summary of Computational Results

	Schedule No.	Minimum pumping time minutes 20	25	30	35	40	45	60
No. of pumpings	1	35	28	30	28	28	23	20
	2	21	12	12	11	10	7	12
	3	16	19	20	18	18	18	12
	4 & 5	65	54	54	52	46	48	40
	6	19	20	20	25	21	15	16
Volume pumped, bbls	1	38,524	38,221	41,720	40,983	38,693	38,766	38,886
	2	16,356	13,615	13,828	14,624	12,807	14,291	16,102
	3	28,596	31,530	31,399	27,394	32,056	34,188	23,621
	4 & 5	70,220	74,474	65,398	68,410	70,153	64,999	76,191
	6	32,100	32,227	28,548	30,955	31,216	26,543	30,232
Interface created bbls	1	2,600	2,600	2,600	2,400	2,600	2,600	2,400
	2	0	0	0	0	0	0	0
	3	3,600	3,500	2,800	2,800	3,300	3,400	2,500
	4 & 5	3,500	4,500	3,600	4,200	4,300	4,400	5,200
	6	1,200	1,000	1,000	1,600	2,000	1,000	1,200
Ratio of interface volume to total volume, in percentage	1	6.75	6.80	6.23	5.86	6.72	6.71	6.17
	2	0	0	0	0	0	0	0
	3	12.59	11.10	8.92	10.22	10.29	9.95	10.58
	4 & 5	4.98	6.04	5.50	6.14	6.13	6.77	6.82
	6	3.43	3.10	3.50	5.17	6.41	3.77	3.97
Average No. of pumpings per day		7.42	6.34	6.48	6.38	5.85	5.28	4.76
Average ratio of interface volume to total volume , in percentage		5.90	6.10	5.30	6.02	6.60	6.40	6.10
Percentage improvement over pipeline company's schedules		28.9	26.5	36.1	27.5	20.5	22.9	26.5

though not monotonically, as the minimum allowable pumping time is increased. There is no apparently significant change in the total interface volume created and total volume pumped during the same schedule period for various minimum pumping times. Long production periods do not always result in a large number of pumpings. As an example, for the minimum pumping time of 45 minutes, there were 23 pumpings during the first production period which lasted 96 hours, while 18 pumpings took place during a production period which lasted 120 hours. It appeared that, the higher the production rates at the gas plants and the larger the number of products produced in a period, the greater are the number of pumpings. The second schedule, for all minimum pumping times, has 0 bbls of interface volume created, while the fourth schedule, for the minimum pumping time of 60 minutes, has the highest interface volume of 5,200 bbls. The average ratio of the total volume of interface created to total volume of products pumped, ranges from 5.30% to 6.60%, the best ratio being obtained for a minimum pumping time of 30 minutes. Also the best ratio of 5.30% represents an improvement of 36.10% over pipeline company's average ratio of 8.30%. The average number of pumpings per day for the minimum pumping time of 30 minutes, is 6.48 which is higher than the pipeline company's average of 5.57, by 14.2%. The program did not report any infeasibility during any of the six production periods. Product PB was always pumped satisfying its imposed restrictions.

Figure 4.1 shows the relationship between the minimum pumping times and the average ratio of interface volume created to the total volume of products pumped. If the variation in production conditions at all gas

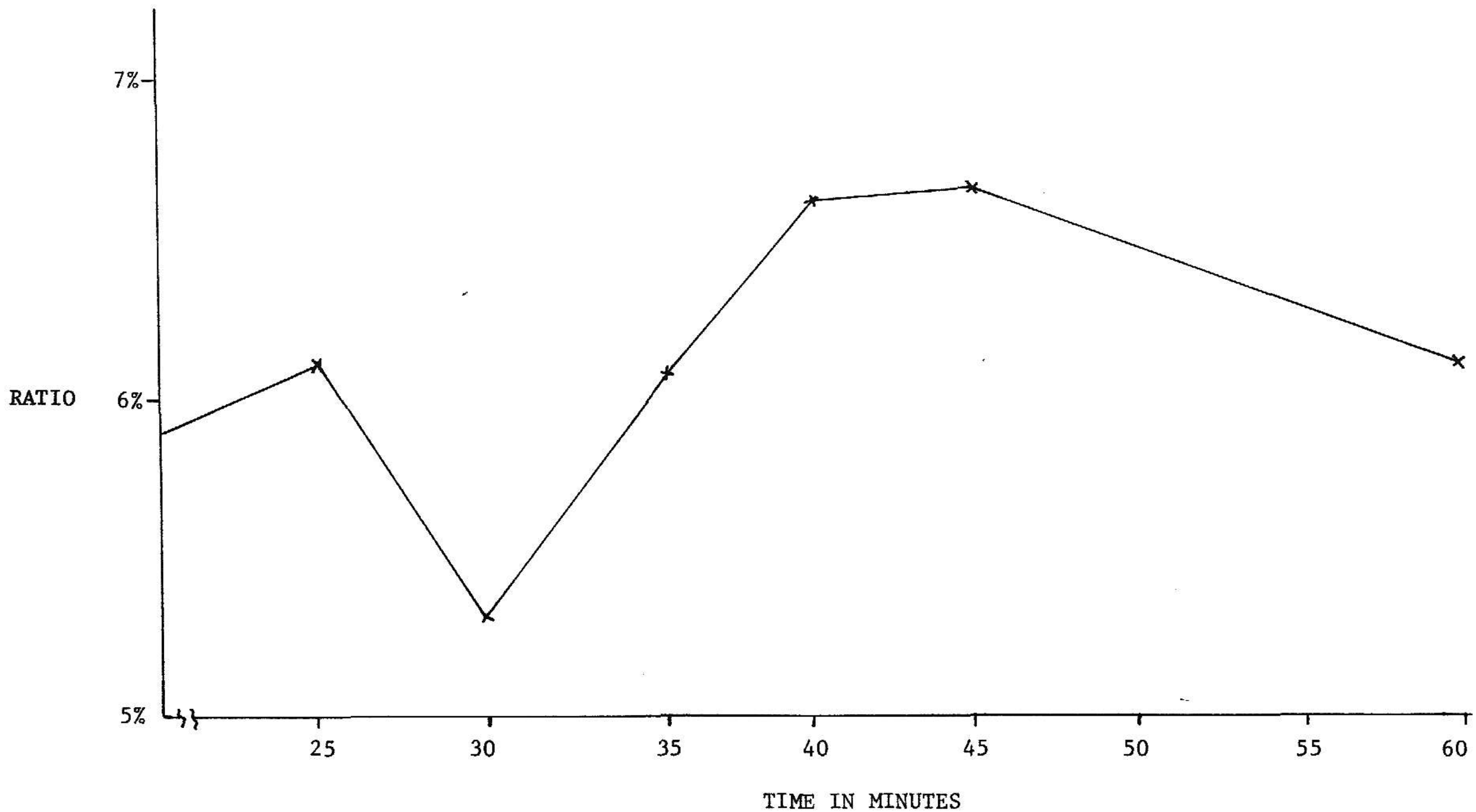


Fig. 4.1. Minimum Pumping Time Versus the Ratio of the Interface Volume to the Total Volume of the Products Pumped

plants is always similar to the variation found in the six production periods under consideration, it may be concluded that the minimum pumping time of 30 minutes is most likely to produce the minimum average volume of interfaces.

CHAPTER V

SUMMARY AND CONCLUSIONS

A major pipeline company in the U.S.A. owns and operates a single, multi-product pipeline which serves a group of nine gas plants. Each gas plant has a pump station which stores the products produced by the gas plant in storage tanks and pumps them through the pipeline at regular intervals. Six different products are made at the gas plants. When different products flow one behind the other in the pipeline, various types of interfaces are formed; each interface representing a certain volume of degraded product. Since a degraded product fetches less price than a pure product, it is essential that the six products are scheduled in such a way that a minimum number of interfaces is created.

The Scheduling and Dispatching Division of the pipeline company uses a computer program which checks the feasibility of a hand-calculated sequence of pumpings, furnished by an experienced scheduler. By feasibility, it is meant that the level of all products in their storage tanks ranges between the maximum and minimum safe levels at all times. The program, however, does not evaluate the sequences in terms of the interfaces created, and consequently, it is not known how good such a schedule is.

This research has made an attempt at formulating a systematized scheduling procedure, based on a set of scheduling rules. The procedure was presented in the form of an algorithm, and its usefulness was demonstrated by generating a schedule. The algorithm was further tested by incorporating it in a simulation program. An important feature of this algorithm is that it identifies and keep a count of interfaces created during a schedule period. Consequently, the measure of performance, which is the ratio of the total volume of interface created to the total volume of products pumped was easily evaluated. Seven different sets of schedules were generated, based on seven different minimum allowable pumping times. It was found that the average volume of interface created per barrel of product pumped, was only 0.053 bbl when schedules were generated with the proposed method. The pipeline company's procedure, however, created 0.083 bbl of interface per barrel of products pumped.

The important difference between the existing and proposed method is that while the former generates stationary schedules, the latter produces non-stationary schedules. A stationary schedule does not have idle periods of the pipeline in between pumpings; but a non-stationary schedule does. It can be claimed that a stationary schedule possesses certain advantages such as: (1) total number of pumping during the schedule period is generally low; (2) duration of idle period following a schedule period is normally long and therefore the personnel responsible for operating the pumps at pump stations can be assigned to some other jobs; (3) most often, a product from a tank is pumped only once during a schedule; and finally, (4) the length of production period does not form a part of the data. But one disadvantage of such schedules which almost outweighs all the advantages is that in order to maintain the system's feasibility at all times, some products are pumped when actually there is no need to pump them, creating in the process, additional interfaces. Moreover, if the production rates at the gas plants are stepped up by, say, two or three times the present rates, it may not be possible to prepare stationary schedules at all times. Products in some storage tanks, which have low capacities, would reach overflow condition very often and it would be difficult to have a long, uninterrupted idle time after each schedule period.

Although the proposed algorithm was tested for six consecutive production periods and was found to create few interfaces, it can not be claimed, by any means, that its validity was tested exhaustively; but the author had no alternative as the pipeline company was in a position to furnish only a limited amount of data. Also, though the assumption that, only 200 bbls of degraded product is created per interface regardless of its constituent products, is justified in the absence of any contrary data, it is definitely important to consider the precise volume of degraded product created for every pair of products that can be involved in an interface. When these details are available, the interface counter incorporated in the algorithm should be modified suitably.

There is no restriction at the present on the type and amount of products delivered at the delivery point of the pipeline. But in the event of finding any specific demand or a pattern of demand, at the delivery point, the algorithm should be suitably modified and it is in this area that further research is suggested. Finally, it should be pointed out that with the present assumptions, the possibility of further improvement of the proposed algorithm itself should be investigated.

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APPENDIX A

List of variables in the program used for analyzing the pipeline company's schedules.

List of Variables

NPS	Number of products in the pipeline.
NP	Pumping sequence number.
	After NP-th pumping, the six different attributes of Jth product in the pipeline are as follows:
IP(NP,J,1)	Type code.
IP(NP,J,2)	Beginning co-ordinate.
IP(NP,J,3)	Ending co-ordinate.
IP(NP,J,4)	Type code of (J-1)-th product.
IP(NP,J,5)	Type code of (J+1)-th product.
IP(NP,J,6)	Volume of the product.
IFACE	Total interface volume in the pipeline.
NENSL	Total number of schedules to be analyzed.
LIMIT	Termination point of the pipeline.
NREF	Station number.
FCNT	Additional number of interfaces created.
ITOTV	Total volume of products pumped.
LOC	Location of the station on the pipeline.
IZ	Type code of the product pumped.
NBVOL	Volume of the product pumped.
IADD	Additional volume of interface created after a pumping.
NOIF	Total number of interfaces present in the pipeline.
INX	Type of interface created.
NOSDL	Schedule number.
RATIO	Ratio of interface volume to total volume.

APPENDIX B

Flow chart of the program used for analyzing the pipeline company's schedules.

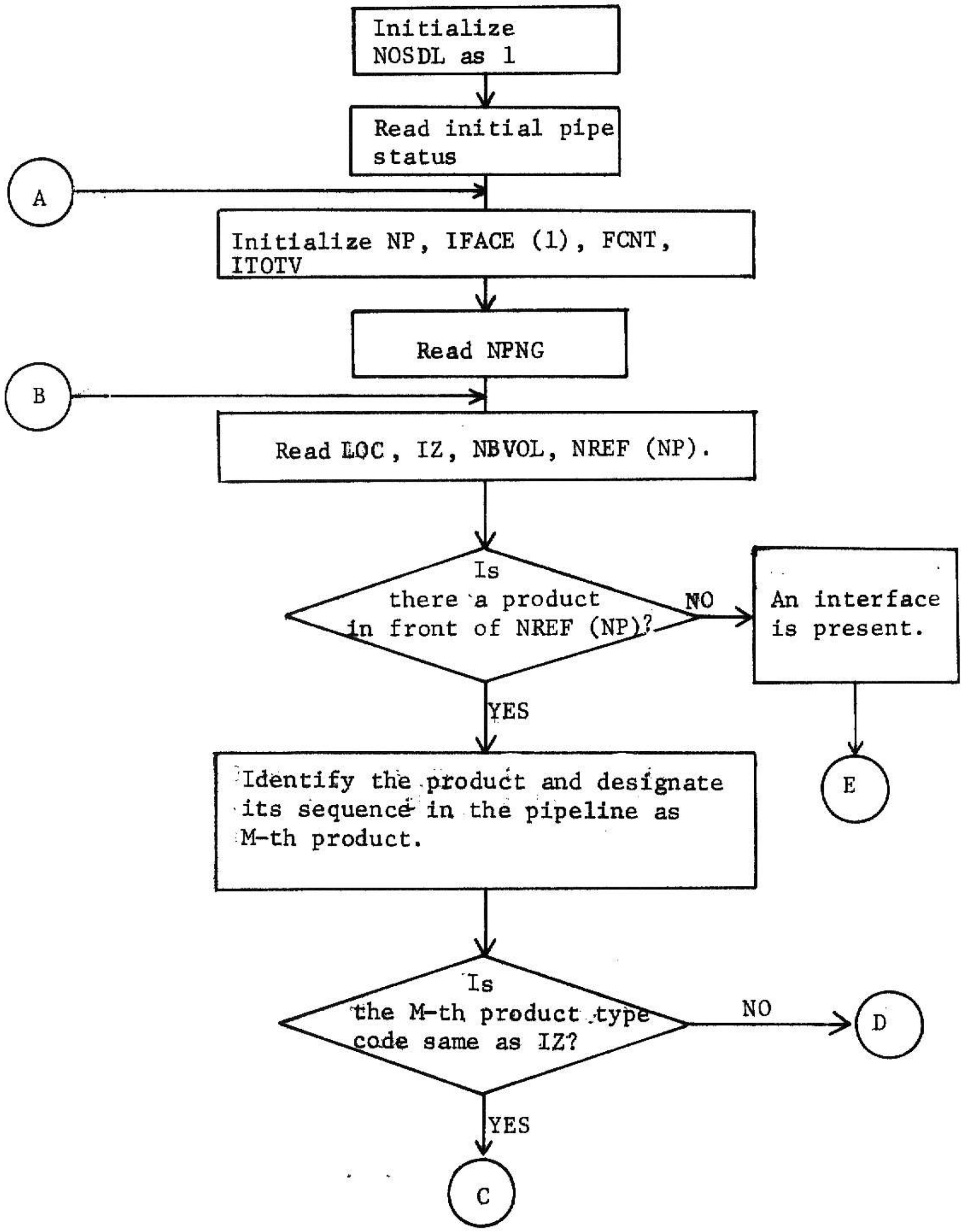

Fig. B.1. Main Program

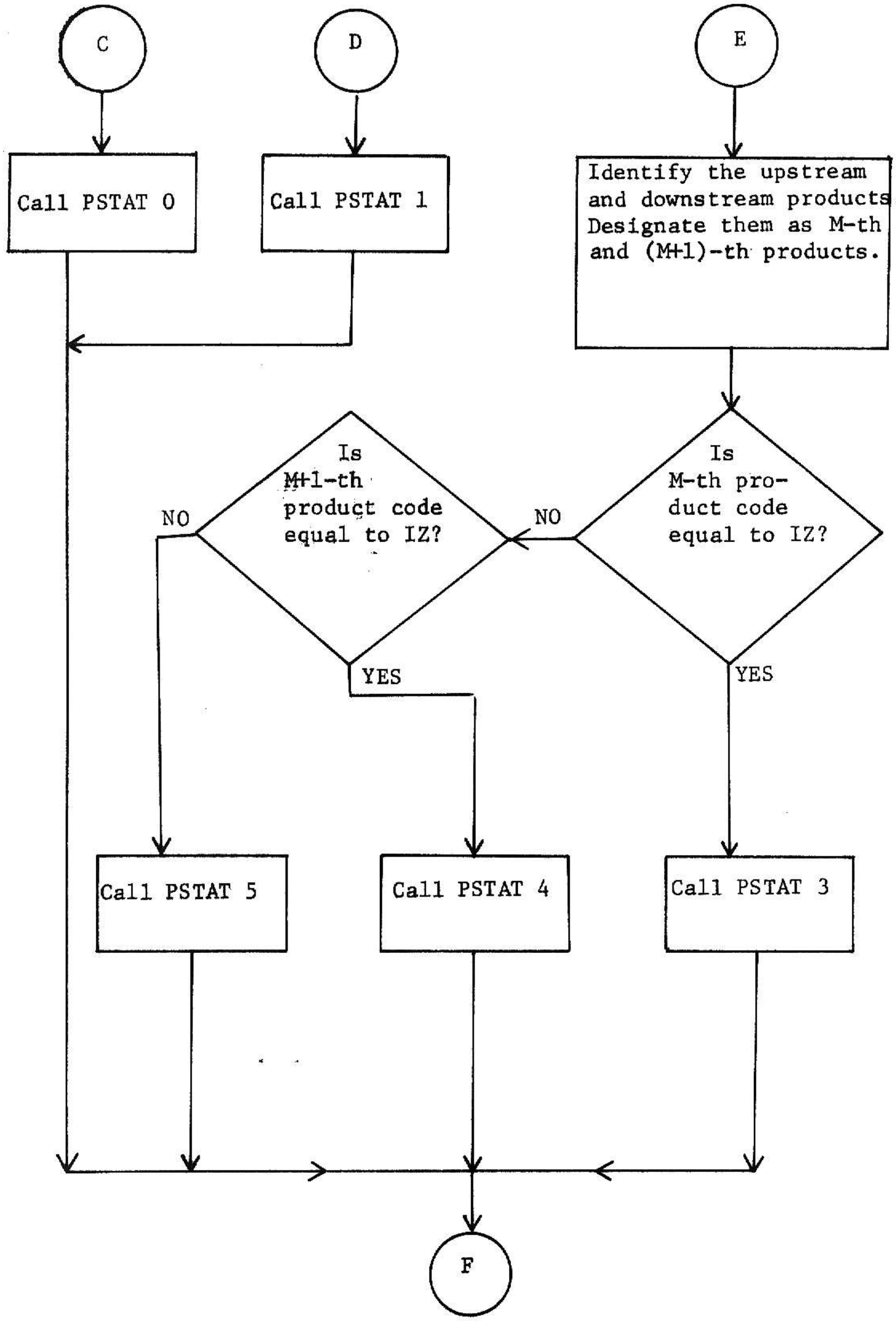

Fig. B.1 Main Program (continued)

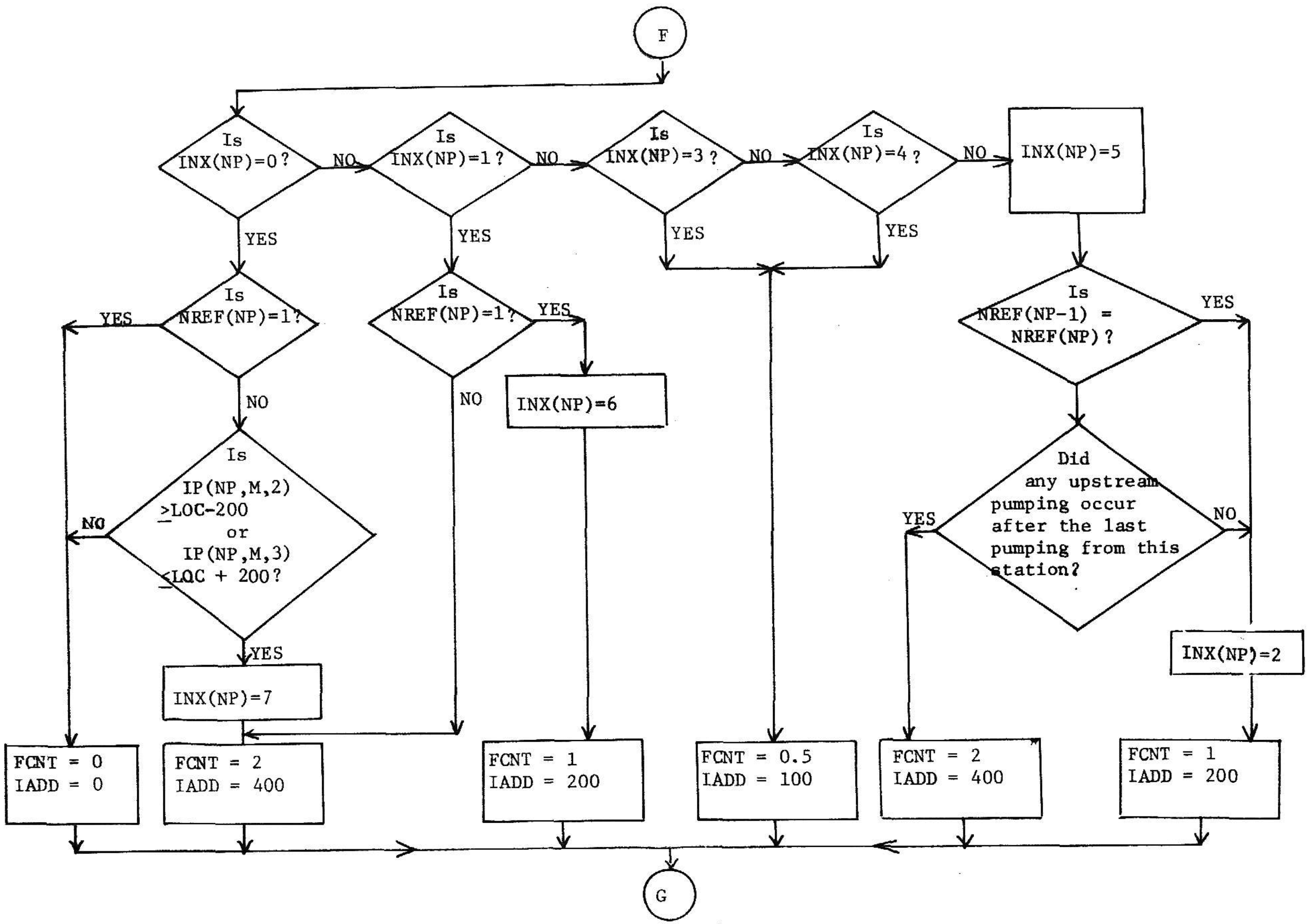

Fig. B.1 Main Program (continued)

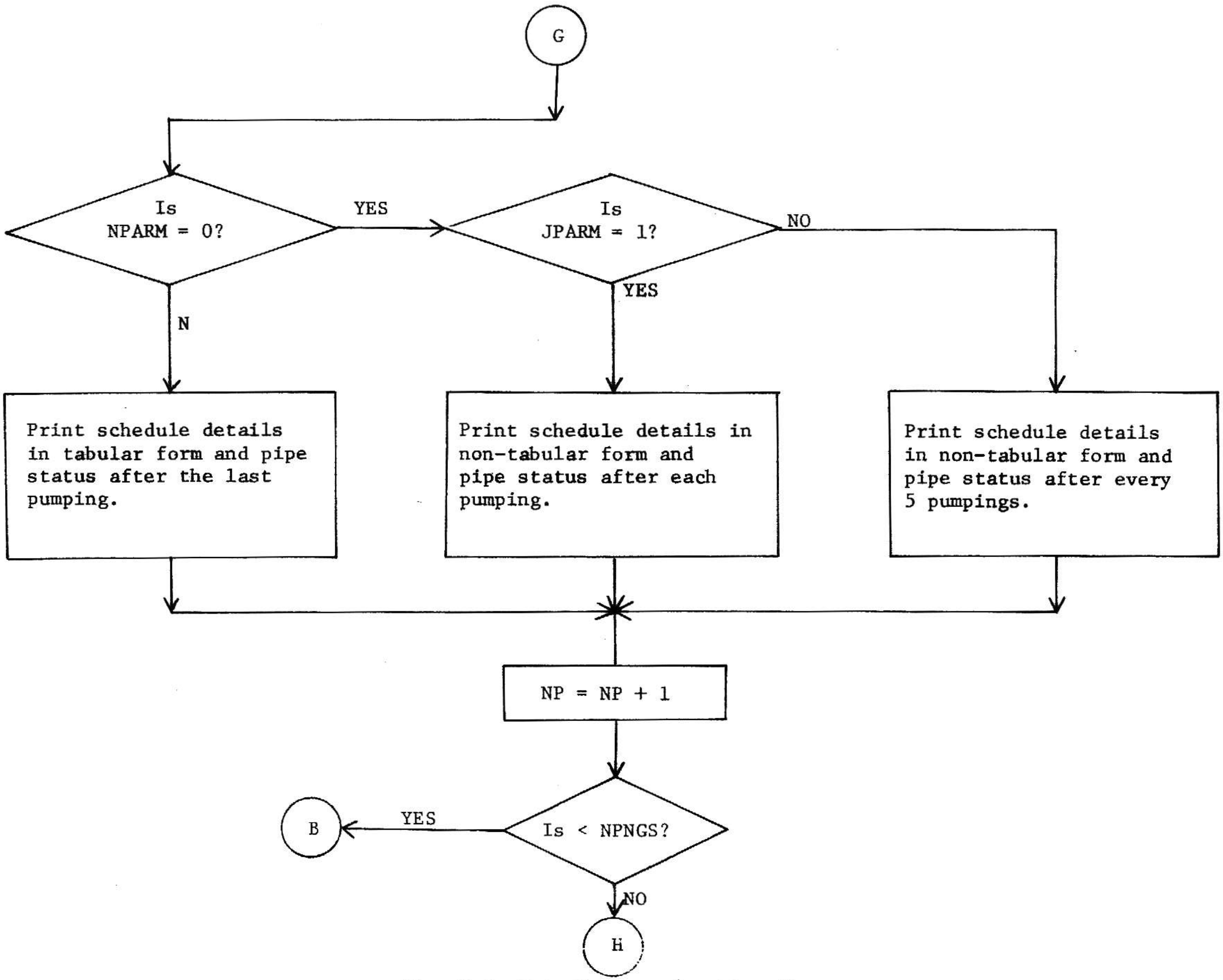

Fig. B.1 Main Program (continued)

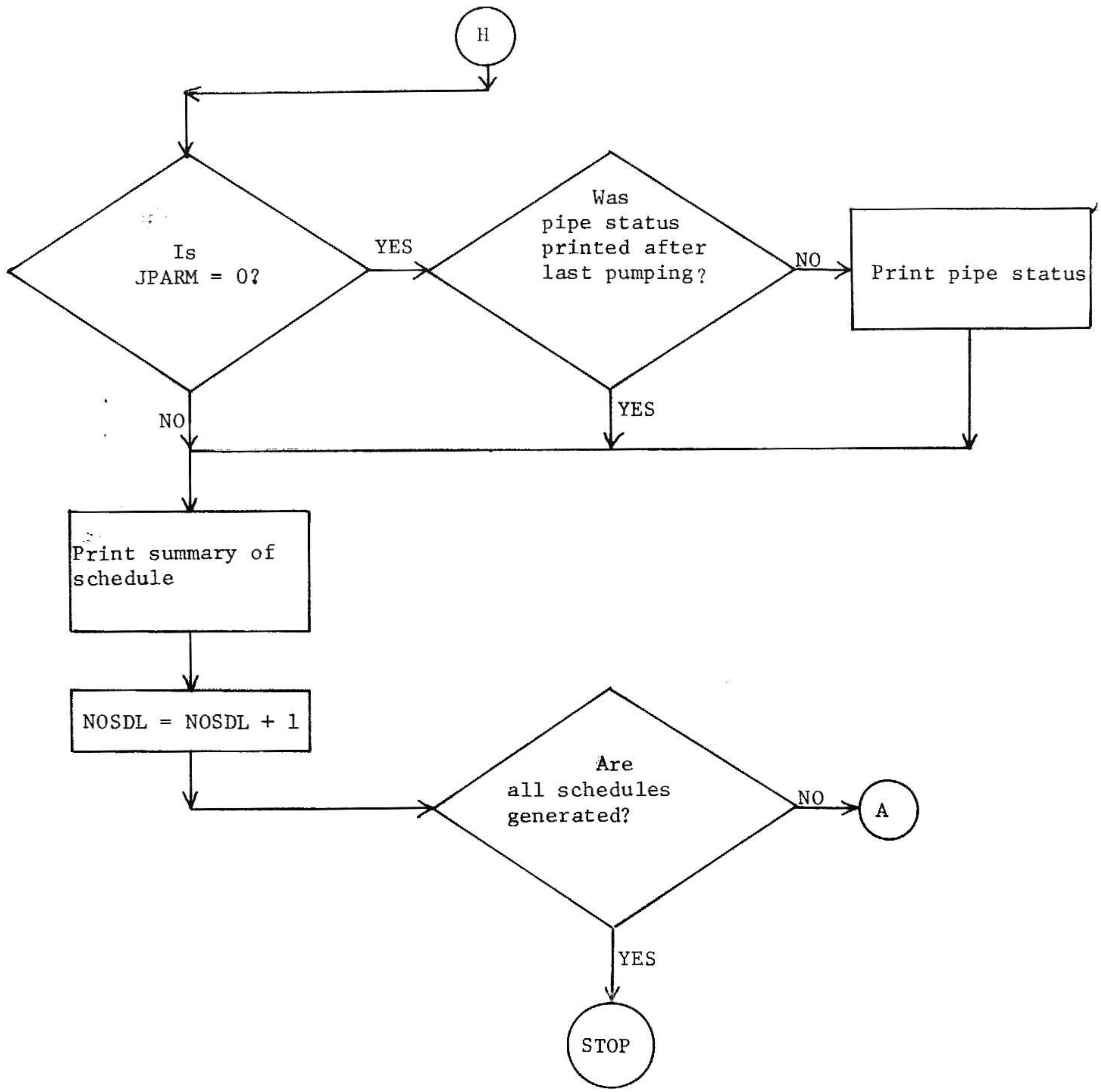

Fig. B.1 Main Program (continued)

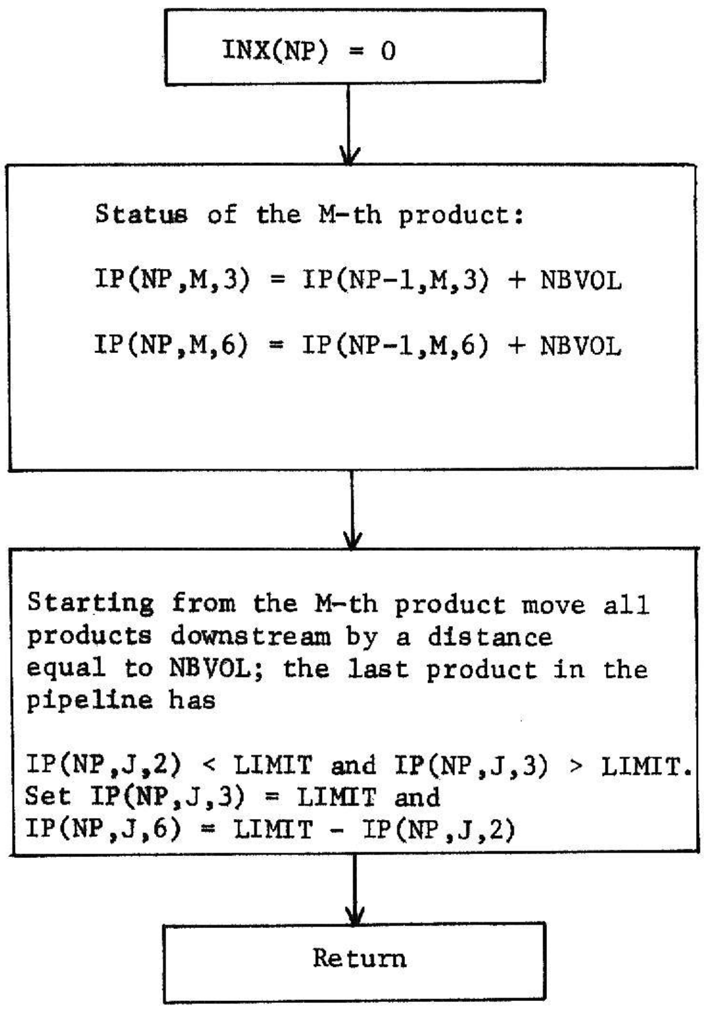

Fig. B.2. Subroutine PSTATO

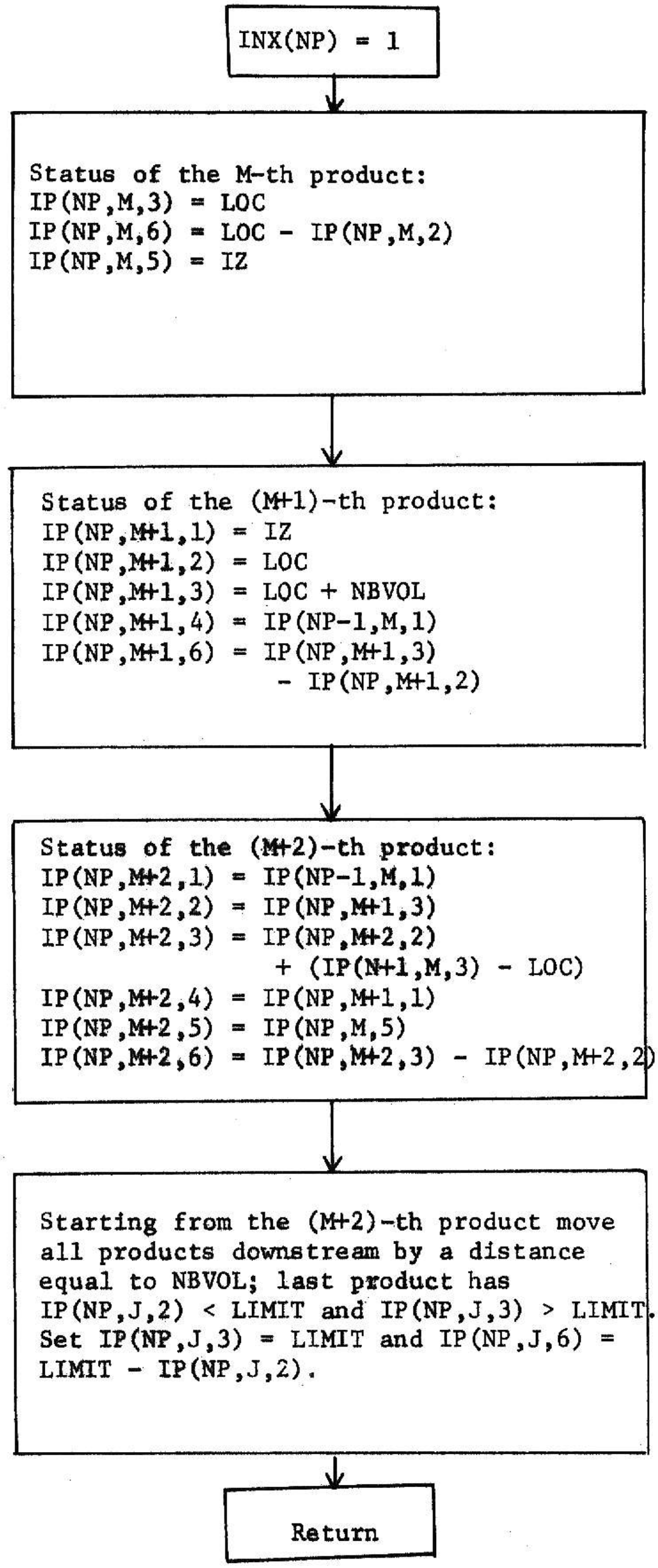

Fig. B.3. Subroutine PSTAT1

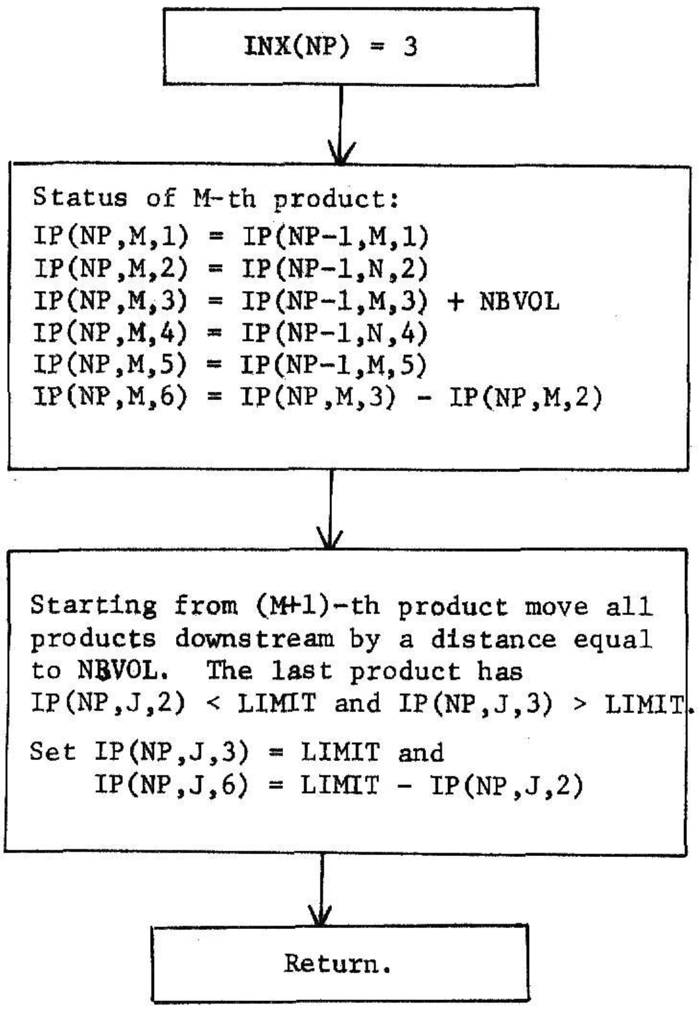

Fig. B.4. Subroutine PSTAT3

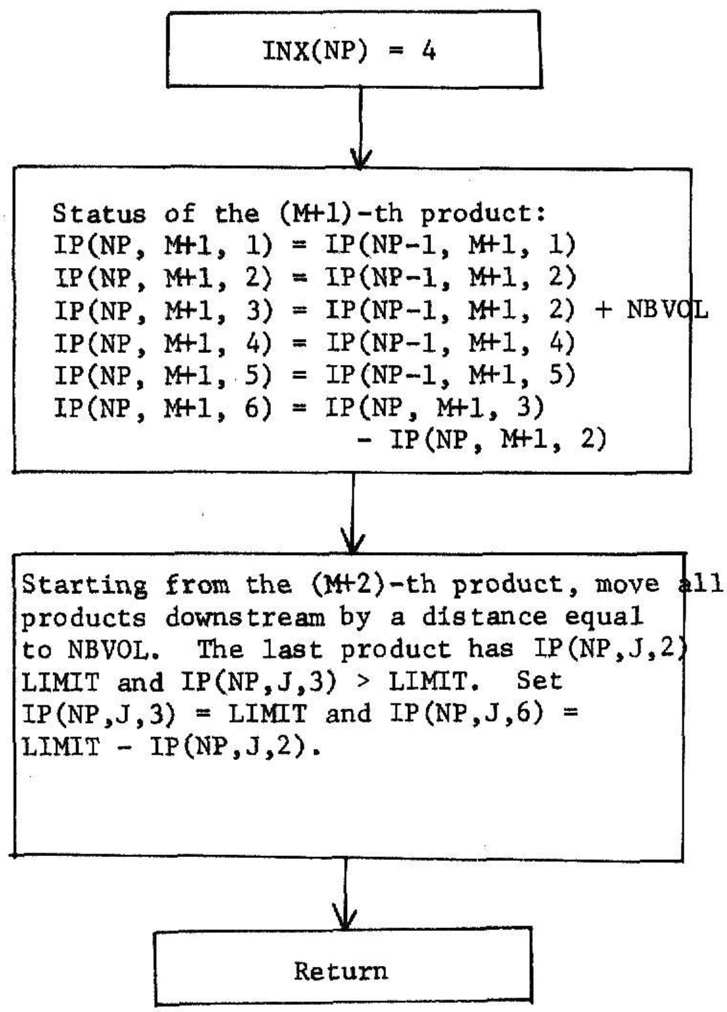

Fig. B.5. Subroutine PSTAT4

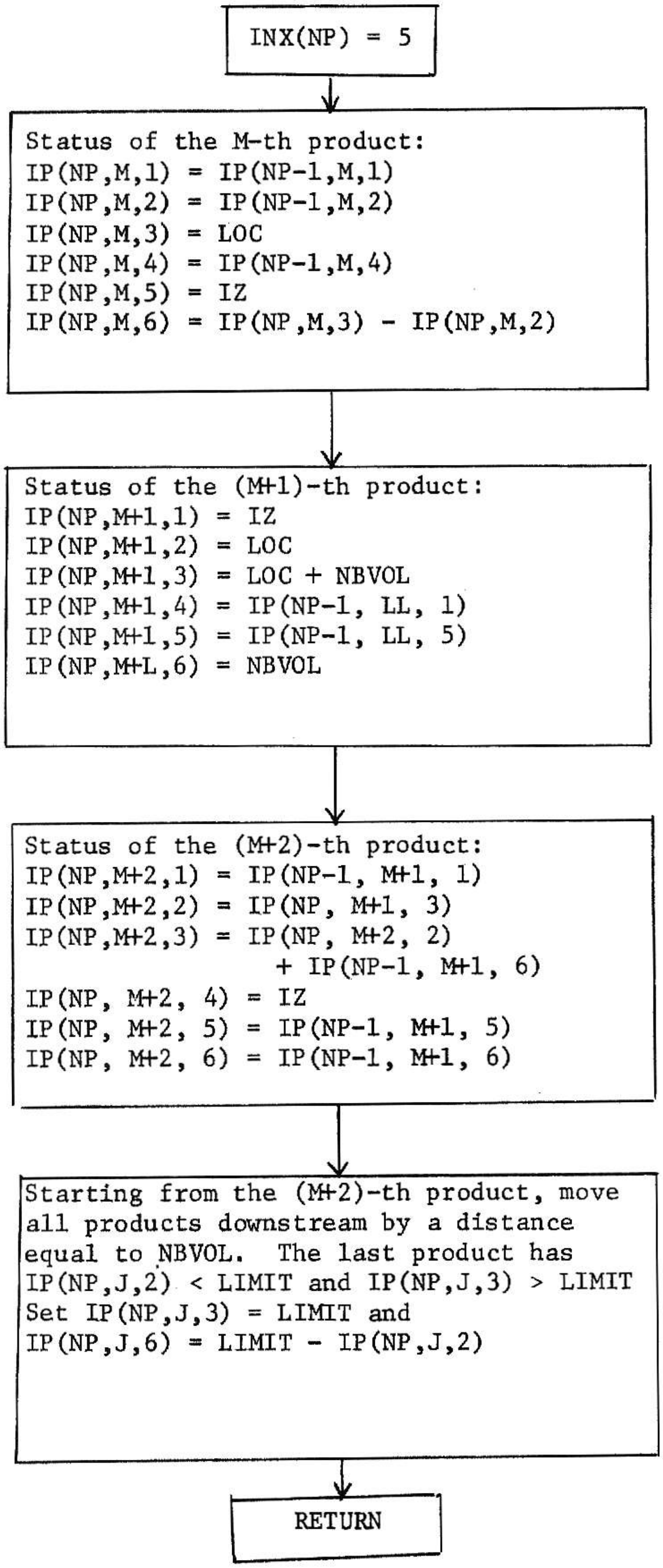

Fig. B.6. Subroutine PSTAT5

APPENDIX C

The program used for analyzing the pipeline company's schedules.

THE
FOLLOWING
DOCUMENT HAS
PRINTING THAT
EXTENDS INTO
THE BINDING.

THIS IS AS
RECEIVED FROM
CUSTOMER.

```
C
C
C
C         THIS PROGRAM WAS WRITTEN TO EVAUATE THE RATIO
C         OF TOTAL INTERFACE VOLUME  TO TOTAL VOLUME OF PRODUCTS
C         PUMPED FROM PIPELINE COMPANY'S SCHEDULE DATA.
C
C         FOR DESCRIPTION OF VARIABLES SEE 'LIST OF VARIABLES'.
C
C
C
      COMMON IP(30,25,6),INX(30),IFACE(30),NREF(30)
      COMMON IZ,NBVOL,LOC,LL,NP,NPS,LIMIT
C
C         NCRDR IS CARD READER AND NPRNT IS THE PRINTER.
      NCRDR=1
      NPRNT=3
C
C
C         TYPE OF OUTPUT.
C
C         IF NPARM=1, WHETHER JPARM=0 OR 1, SCHEDULE DETAILS
C         WILL BE PRINTED OUT IN TABULAR FORM.
C
C         IF NPARM=0, JPARM SHOULD HAVE A VALUE EITHER 0 OR 1.
C         IF JPARM=0, PIPE STATUS WILL BE PRINTED OUT AFTER
C         EVERY 5 PUMPINGS. IF JPARM=1, PIPE STATUS WILL
C         BE PRINTED OUT AFTER EVERY PUMPING.
C         NOTE: WHEN NPARM=0, PIPE STATUS WILL BE PRINTED OUT
C         IN VECTOR FORM.
C
      NPARM=1
      JPARM=0
C
C         FORMAT STATEMENTS.
C
   10 FORMAT(10I6)
   20 FORMAT('1',5X,'BEGINNING OF SCHEDULE NO: 1',//)
   21 FORMAT('0',5X,'PUMPING',3X,'STATION',3X,'PRODUCT',3X,'VOLUME',3X,
     1'TYPE OF',3X,'INFACE',/' ',3(7X,'NO.'),5X,'PUMPED',4X,'INFACE',
     24X,'VOL',/' ',36X,'BBLS',15X,'BBLS',//)
  476 FORMAT('1',30X,'THE DETAILS OF THE SCHEDULE ARE:')
 3360 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.1')
 3380 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.2')
 3400 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.3')
 3420 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.5')
 3440 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.6')
 3460 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.7')
```

```
 3454 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.4')
 3458 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.9')
 3470 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.8')
 3510 FORMAT(' ',5X,'VOLUME PUMPED:',I10)
 3511 FORMAT(' ',5X,'THE PRODUCT PUMPED:',I3)
 3520 FORMAT('0',5X,'THE PIPE STATUS AT THE END OF LAST PUMPING:')
 3521 FORMAT('0',5X,'PRODUCT SEQUENCE NO:',I2)
 3550 FORMAT(' ',5X,'IP(',I3,',',I2,',',I2,')=',I10)
 3570 FORMAT('0',5X,'TYPE OF INTERFACE CREATED:',I3)
 3575 FORMAT(' ',5X,'NO.OF INTERFACES THIS STEP:',I3)
 3580 FORMAT(' ','ADDITIONAL INTERFACE THIS STEP:',I6,' BBLS')
 3590 FORMAT(' ',5X,'TOTAL INTERFACE SO FAR:',I6,' BBLS')
 3576 FORMAT(' ',5X,'INTERFACE VOLUME AT THE BEGINNING OF SCHEDULE:',I8,
     1' BBLS')
 3597 FORMAT(' ',5X,'TOTAL VOLUME PUMPED SO FA:',I8,' BBLS')
 3705 FORMAT(' ',7X,I2,2(8X,I2),7X,I4,7X,I2)
 3710 FORMAT('+',56X,I3)
 5555 FORMAT('0',5X,'PRODUCT',5X,'PRODUCT',4X,'BEGINING',4X,'ENDING',
     14X,'VOLUME',/' ',5X,'SEQUENCE',6X,'CODE',7X,'POINT',6X,'POINT',
     25X,'BBLS',/' ',8X,'NO.',9X,'NO.',8X,'BBLS',7X,'BBLS',/)
 5556 FORMAT(' ',8X,I2,10X,I2,7X,I6,5X,I6,4X,I6)
 3600 FORMAT('-',5X,'END OF SCHEDULE: SUMMARY.')
 3610 FORMAT('0',5X,'NUMBER OF PUMPINGS IN THIS PERIOD IS:',I3)
 3620 FORMAT(' ',5X,'TOTAL NUMBER OF INTERFACES CREATED IN THIS PERIOD
     1IS:',F6.2)
 3630 FORMAT(' ',5X,'TOTAL INTERFACE VOLUME CREATED IN THIS PERIOD IS:'
     1,I8,' BBLS')
 3631 FORMAT(' ',5X,'TOTAL VOLUME PUMPED IN THIS PERIOD:',I8,' BBLS')
 3640 FORMAT(' ',5X,'RATIO OF INTERFACE VOL TO TOTAL VOL:',F6.2,' %')
 3685 FORMAT('0',5X,'INTERFACE VOLUME AT THE START OF NEXT SCHEDULE:',
     1I6,' BBLS')
      READ(NCRDR,10) NPS
      DO 15 J=1,NPS
      READ(NCRDR,10) (IP(1,J,K),K=1,6)
   15 CONTINUE
      READ (NCRDR,10) IFACE(1),NENSL,LIMIT
      NOSDL=1
      WRITE(NPRNT,20)
C
   50 NP=2
      NREF(1)=0
      FCNT=0.0
      ITOTV=0
      WRITE(NPRNT,21)
      READ (NCRDR,10) NPNGS
C
  100 READ (NCRDR,10) LOC,IZ,NBVOL,NREF(NP)
C
```

```
C          UPDATE THE PIPE STATUS.
C
  500 DO 501 K=1,NPS
      LL=K
      IF(IP(NP-1,K,3).EQ.LOC) GO TO 1000
  501 CONTINUE
C          SINCE THERE IS NO INTERFACE IDENTIFY THE PRODUCT
  505 DO 510 K=1,NPS
      LL=K
      IF((IP(NP-1,K,2).LT.LOC).AND.(IP(NP-1,K,3).GT.LOC)) GO TO 520
  510 CONTINUE
C          LL NOW GIVES THE PRODUCT SEQUENCE NO
C          CHECK IF A NEW INTERFACE IS CREATETED
  520 IF(IP(NP-1,LL,1).EQ.IZ) GO TO 750
C          NEW INTERFACE IS CREATED
      GO TO 525
  750 CALL PSTATO
      GO TO 3000
  525 CALL PSTAT1
      GO TO 3000
C          THE PRODUCT TO BE PUMPED MEETS AN INTERFACE
C          IT IS POSSIBLE THAT THE PRODUCT TO BE PUMPED IS SAME AS
C            A. PRODUCT TO THE LEFT OF INTERFACE
C            B. PRODUCT TO THE RIGHT OF INTERFACE
C            C. NEITHER OF THESE TWO PRODUCTS
C
 1000 IF(IP(NP-1,LL,1).EQ.IZ) GO TO 1010
      GO TO 1020
 1010 CALL PSTAT3
      GO TO 3000
 1020 IF(IP(NP-1,LL+1,1).EQ.IZ) GO TO 1031
      CALL PSTAT5
      GO TO 3000
 1031 CALL PSTAT4
      GO TO 3000
C
C
C          INTERFACE COUNTER
C
C
C          CHECK FOR TYPE 0 INTERFACE.
 3000 IF (INX(NP).EQ.0) GO TO 3010
      GO TO 3011
C          CHECK FOR TYPE 1 INTERFACE.
 3010 IFACE(NP)=IFACE(NP-1)
      GO TO 3050
 3011 IF(INX(NP).EQ.1) GO TO 3012
      GO TO 3013
```

```
 3012 IF(NREF(NP).EQ.1) GO TO 3026
      IF((NREF(NP).EQ.NREF(NP-1)).AND.(INX(NP-1).NE.0)) GO TO 3028
      IFACE(NP)=IFACE(NP-1)+400
      FCNT=FCNT+2.0
      GO TO 3050
C        CHECK FOR TYPE 3 OR 4 INTERFACE.
 3013 IF((INX(NP).EQ.3).OR.(INX(NP).EQ.4)) GO TO 3014
      GO TO 3015
 3014 IFACE(NP)=IFACE(NP-1)+100
      FCNT=FCNT+0.5
      GO TO 3050
C        CHECK FOR TYPE 5 INTERFACE.
 3015 IF(INX(NP).EQ.5) GO TO 3025
      IF(INX(NP).EQ.7) GO TO 3039
      GO TO 6000
 3025 IF(NREF(NP).EQ.1) GO TO 3026
      GO TO 3027
 3026 INX(NP)=6
      GO TO 3040
 3027 IF(NREF(NP).EQ.NREF(NP-1)) GO TO 3028
      GO TO 3035
 3028 INX(NP)=2
      GO TO 3040
C        CHECK IF ANY DOWNSTREAM PUMPING OCCURED AFTER THE
C        LAST PUMPING FROM THIS STATION. IF NO DOWNSTREAM
C        PUMPING OCCURED,EVEN UNDER TYPE 5 CONDITION THE NUMBER
C        OF INTERFACES CREATED IS ONLY ONE.
 3035 NQ=NP-1
      IF(NQ.EQ.1) GO TO 3039
 3038 IF(NREF(NQ).LT.NREF(NP)) GO TO 3039
      NQ=NQ-1
      IF(NQ.EQ.1) GO TO 3039
      IF(NREF(NQ).EQ.NREF(NP)) GO TO 3028
      GO TO 3038
 3039 IFACE(NP)=IFACE(NP-1)+400
      FCNT=FCNT+2.0
      GO TO 3050
 3040 IFACE(NP)=IFACE(NP-1)+200
      FCNT=FCNT+1.0
 3050 NOIF=NPS-1
      IADD=IFACE(NP)-IFACE(NP-1)
      ITOTV=ITOTV+NPVOL
C
C        PRINT STATEMENTS. NOTE THAT THESE STATEMENTS ARE COMPLETELY
C        SKIPPED IF NPARM=1.
C
      IF(NPARM.EQ.1) GO TO 3700
      IF(LOC.NE.1) GO TO 3350
```

```
      WRITE(NPRNT,3360)
      GO TO 3500
 3350 IF(LOC.NE.1209) GO TO 3370
      WRITE (NPRNT,3380)
      GO TO 3500
 3370 IF(LOC.NE.4060) GO TO 3390
      WRITE(NPRNT,3400)
      GO TO 3500
 3390 IF(LOC.NE.15604) GO TO 3410
      WRITE(NPRNT,3420)
      GO TO 3500
 3410 IF(LOC.NE.19504) GO TO 3430
      WRITE (NPRNT,3440)
      GO TO 3500
 3430 IF(LOC.NE.24671) GO TO 3450
      WRITE (NPRNT,3460)
      GO TO 3500
 3450 IF(LOC.NE.13124) GO TO 3452
      WRITE (NPRNT,3454)
      GO TO 3500
 3452 IF(LOC.NE.24672) GO TO 3456
      WRITE(NPRNT,3458)
      GO TO 3500
 3456 WRITE(NPRNT,3470)
 3500 WRITE(NPRNT,3510) NBVOL
      WRITE (NPRNT,3511) IZ
C
C        PRINT OUT PIPE STATUS AFTER EVERY 5 PUMPINGS
C        IF JPARM=0
C
      IF(JPARM.EQ.1) GO TO 3519
      NR=MOD(NP,5)
      IF(NR.EQ.0) GO TO 3519
      GO TO 3596
 3519 WRITE(NPRNT,3520)
      NPP=NP-1
      DO 3530 J=1,NPS
      WRITE (NPRNT,3521) J
      DO 3540 K=1,6
      WRITE(NPRNT,3550) NPP,J,K,IP(NP,J,K)
 3540 CONTINUE
 3530 CONTINUE
 3535 WRITE(NPRNT,3570) INX(NP)
      WRITE (NPRNT,3575) NOIF
      WRITE (NPRNT,3580) IADD
      WRITE (NPRNT,3590) IFACE(NP)
      WRITE(NPRNT,3576) IFACE(1)
      WRITE(NPRNT,3597) ITOTV
```

```
      GO TO 3596
C
C        THE FOLLOWING PRINTING STATEMENTS ARE EXECUTED ONLY
C        IF NPARM=1.
C
 3700 NPP=NP-1
      WRITE(NPRNT,3705) NPP,NREF(NP),IZ,NBVOL,INX(NP)
      IF(INX(NP).NE.0) WRITE(NPRNT,3710) IADD
C
C        INCREASE PUMPING NO BY ONE AND UPDATE THE PRESENT
C        TIME.
C
 3596 NP=NP+1
C
      IF (NP.LE.(NPNGS+1)) GO TO 100
 3598 NPP=NP-1
      NPQ=NP-2
      IF (NPARM.EQ.1) GO TO 4000
      IF (JPARM.EQ.1) GO TO 3599
      NR=MOD(NPP,5)
      IF(NR.NE.0) GO TO 4000
      GO TO 3599
C        PRINT THE PIPE STATUS.
 4000 WRITE (NPRNT,3520)
      WRITE(NPRNT,5555)
      DO 4100 J=1,NPS
      WRITE(NPRNT,5556) J,IP(NPP,J,1),IP(NPP,J,2),IP(NPP,J,3),
     1IP(NPP,J,6)
 4100 CONTINUE
 3599 IFNP=NP-2
      IXIF=IFACE(NP-1)-IFACE(1)
C        PRINT THE SUMMARY OF THE SCHEDULE.
      WRITE(NPRNT,3600)
      WRITE(NPRNT,3610) IFNP
      WRITE(NPRNT,3620) FCNT
      WRITE(NPRNT,3630) IXIF
      WRITE (NPRNT,3631) ITOTV
      RATIO=(FLOAT(IXIF)/FLOAT(ITOTV))*100.0
      WRITE (NPRNT,3640) RATIO
      DO 3675 I=1,NPS
      DO 3680 J=1,6
      IP(1,I,J)=IP(NP-1,I,J)
 3680 CONTINUE
 3675 CONTINUE
      IFACE(1)=NOIF*200
      NOSDL=NOSDL+1
      WRITE (NPRNT,200) NOSDL
  200 FORMAT('1',5X,'BEGINNING OF SCHEDULE NO:',I3,//)
```

```
      IF(NOSDL.GT.NENSL) GO TO 6000
      GO TO 50
 6000 STOP
      END
```

```
      SUBROUTINE PSTATO
C
C        THIS SUBROUTINE UPDATES THE PIPE STATUS IF TYPE 0 INTERFACE
C        IS CREATED
C
      COMMON IP(30,25,6),INX(30),IFACE(30),NREF(30)
      COMMON IZ,NBVOL,LOC,LL,NP,NPS,LIMIT
C
      INX(NP)=0
      IF(NREF(NP).EQ.1) GO TO 751
      IF((IP(NP-1,LL,2).GT.(LOC-200)).OR.(IP(NP-1,LL,3).LT.(LOC+200)))IN
     1X(NP)=7
  751 IP(NP,LL,1)=IP(NP-1,LL,1)
      IP(NP,LL,2)=IP(NP-1,LL,2)
      IP(NP,LL,3)=IP(NP-1,LL,3)+NBVOL
      IP(NP,LL,4)=IP(NP-1,LL,4)
      IP(NP,LL,5)=IP(NP-1,LL,5)
      IP(NP,LL,6)=IP(NP-1,LL,6)+NBVOL
C        CHECK IF THE PRODUCT TO BE PUMPED WILL OCCUPY THE ENTIRE
C        VOLUME TO THE RIGHT
      IF(IP(NP,LL,3).GE.LIMIT) GO TO 760
      GO TO 770
  760 IP(NP,LL,3)=LIMIT
      IP(NP,LL,5)=0
      IP(NP,LL,6)=LIMIT-IP(NP,LL,2)
      NNPS=LL
C        GO TO STATEMENT 800 TO UPDATE THE STATUS OF ALL PRODUCTS
C        TO THE LEFT OF LOC
      GO TO 800
C        UPDATE THE STATUS OF ALL PRODUCTS TO THE RIGHT. CHECK SIMULTANEOUS
C        IF THE DELIVERY POINT HAS BEEN REACHED
C
  770 LL1=LL+1
      DO 771 J=LL1,NPS
      NNPS=J
      IP(NP,J,1)=IP(NP-1,J,1)
      IP(NP,J,2)=IP(NP,J-1,3)
      IP(NP,J,3)=IP(NP,J,2)+IP(NP-1,J,6)
      IP(NP,J,4)=IP(NP-1,J,4)
      IP(NP,J,5)=IP(NP-1,J,5)
      IP(NP,J,5)=IP(NP-1,J,6)
      IF(IP(NP,J,3).GE.LIMIT) GO TO 780
  790 GO TO 771
  780 IP(NP,J,3)=LIMIT
      IP(NP,J,5)=0
      IP(NP,J,6)=LIMIT-IP(NP,J,2)
      GO TO 800
  771 CONTINUE
```

```
  800 NPS=NNPS
      LLM=LL-1
      IF(LLM.EQ.0) GO TO 811
      DO 810 J=1,LLM
      DO 820 K=1,6
      IP(NP,J,K)=IP(NP-1,J,K)
  820 CONTINUE
  810 CONTINUE
  811 RETURN
      END
```

```
      SUBROUTINE PSTAT1
C
C        THIS SUBROUTINE UPDATES THE PIPE STATUS IF TYPE 1
C        INTERFACE IS CREATED.
C
      COMMON IP(30,25,6),INX(30),IFACE(30),NREF(30)
      COMMON IZ,NBVOL,LOC,LL,NP,NPS,LIMIT
C
      INX(NP)=1
C        CHECK IF THE VOLUME TO BE PUMPED REPLACES THE ENTIRE VOLUME
C        TO THE RIGHT
      IF(NBVOL.GE.(LIMIT-LOC)) GO TO 530
      GO TO 540
  530 NPS=LL+1
      IP(NP,LL+1,1)=IZ
      IP(NP,LL+1,2)=LOC
      IP(NP,LL+1,3)=LIMIT
      IP(NP,LL+1,4)=IP(NP-1,LL,1)
      IP(NP,LL+1,5)=0
      IP(NP,LL+1,6)=LIMIT-LOC
      GO TO 535
C        NEW PRODUCT DOES NOT REPLACE ENTIRE VOLUME TO THE RIGHT
  540 IP(NP,LL+1,1)=IZ
      IP(NP,LL+1,2)=LOC
      IP(NP,LL+1,3)=LOC+NBVOL
      IP(NP,LL+1,4)=IP(NP-1,LL,1)
      IP(NP,LL+1,5)=IP(NP-1,LL,1)
      IP(NP,LL+1,6)=NBVOL
C        UPDATE STATUS OF SECOND PRODUCT TO THE RIGHT OF LOC
      IP(NP,LL+2,1)=IP(NP-1,LL,1)
      IP(NP,LL+2,2)=IP(NP,LL+1,3)
      IP(NP,LL+2,3)=IP(NP,LL+2,2)+(IP(NP-1,LL,3)-LOC)
      IP(NP,LL+2,4)=IP(NP,LL+1,1)
      IP(NP,LL+2,5)=IP(NP-1,LL,5)
      IP(NP,LL+2,6)=IP(NP,LL+2,3)-IP(NP,LL+2,2)
      IF(IP(NP,LL+2,3).GE.LIMIT) GO TO 551
      GO TO 561
  551 IP(NP,LL+2,3)=LIMIT
      IP(NP,LL+2,5)=0
      IP(NP,LL+2,6)=LIMIT-IP(NP,LL+2,2)
      NPS=LL+2
      GO TO 535
C        SECOND PRODUCT TO THE RIGHT OF LOCATION DID NOT OCCUPY
C        THE FULL VOLUME. UPDATE THE STATUS OF ALL PRODUCTS BEGINNING
C        FROM THE THIRD,CHECKING SIMULTANEOUSLY IF THE DELIVERY
C        POINT HAS BEEN REACHED.
C
  561 NN6=LL+2
```

```
      NN7=NPS+3
      DO 570 J=NN6,NN7
      NNPS=J
      IP(NP,J+1,1)=IP(NP-1,J-1,1)
      IP(NP,J+1,2)=IP(NP,J,3)
      IP(NP,J+1,3)=IP(NP-1,J-1,6)+IP(NP,J+1,2)
      IP(NP,J+1,4)=IP(NP,J,1)
      IP(NP,J+1,5)=IP(NP-1,J-1,5)
      IP(NP,J+1,6)=IP(NP-1,J-1,6)
      IF(IP(NP,J+1,3).GE.LIMIT) GO TO 580
      GO TO 570
  580 IP(NP,J+1,3)=LIMIT
      IP(NP,J+1,5)=0
      IP(NP,J+1,6)=LIMIT-IP(NP,J+1,2)
      NPS=NNPS+1
      GO TO 535
  570 CONTINUE
C        UPDATE THE PRODUCTS BEHIND EXCEPT ONE IMMEDIATELY BEHIND
  535 NN5=LL-1
      IF(NN5.EQ.0) GO TO 555
      DO 550 J=1,NN5
      DO 560 K=1,6
      IP(NP,J,K)=IP(NP-1,J,K)
  560 CONTINUE
  550 CONTINUE
C        UPDATE STATUS OF THE PRODUCT THAT IS IMMEDIATELY BEHIND
  555 IP(NP,LL,1)=IP(NP-1,LL,1)
      IP(NP,LL,2)=IP(NP-1,LL,2)
      IP(NP,LL,3)=LOC
      IP(NP,LL,4)=IP(NP-1,LL,4)
      IP(NP,LL,5)=IZ
      IP(NP,LL,6)=LOC-IP(NP,LL,2)
      RETURN
      END
```

```
      SUBROUTINE PSTAT3
C
C        THIS SUBROUTINE UPDATES THE PIPE STATUS IF
C        TYPE 3 INTERFACE IS CREATED.
C
      COMMON IP(30,25,6),INX(30),IFACE(30),NREF(30)
      COMMON IZ,NBVOL,LOC,LL,NP,NPS,LIMIT
C
      INX(NP)=3
      IP(NP,LL,1)=IP(NP-1,LL,1)
      IP(NP,LL,2)=IP(NP-1,LL,2)
      IP(NP,LL,3)=IP(NP-1,LL,3)+NBVOL
      IP(NP,LL,4)=IP(NP-1,LL,4)
      IP(NP,LL,5)=IP(NP-1,LL,5)
      IP(NP,LL,6)=IP(NP,LL,3)-IP(NP,LL,2)
C        CHECK IF THE PRODUCT TO BE PUMPED OCCUPYS THE ENTIRE VOLUME
C        TO THE RIGHT
      IF(IP(NP,LL,3).GE.LIMIT) GO TO 1028
      GO TO 1030
 1028 IP(NP,LL,3)=LIMIT
      IP(NP,LL,5)=0
      IP(NP,LL,6)=LIMIT-LOC
      NPS=LL
      GO TO 2000
C        THE PRODUCT PUMPED DOES NOT OCCUPY THE ENTIRE VOLUME TO
C        THE RIGHT. UPDATE THE STATUS OF ALL PRODUCTS TO THE RIGHT
C        CHECKING SIMULTANEOUSLY IF THE DELIVERY POINT HAS BEEN REACHED
 1030 NLN=LL+1
      DO 1040 J=NLN,NPS
      NNPS=J
      IP(NP,J,1)=IP(NP-1,J,1)
      IP(NP,J,2)=IP(NP,J-1,3)
      IP(NP,J,3)=IP(NP,J,2)+IP(NP-1,J,6)
      IP(NP,J,4)=IP(NP-1,J,4)
      IP(NP,J,5)=IP(NP-1,J,5)
      IP(NP,J,6)=IP(NP-1,J,6)
      IF(IP(NP,J,3).GE.LIMIT) GO TO 1050
 1040 CONTINUE
 1050 IP(NP,NNPS,3)=LIMIT
      IP(NP,NNPS,5)=0
      IP(NP,NNPS,6)=LIMIT-IP(NP,NNPS,2)
      NPS=NNPS
      GO TO 2000
C        UPDATE THE STATUS OF ALL PRODUCTS TO THE LEFT
 2000 LLNJ=LL-1
      IF(LLNJ.EQ.0) GO TO 2011
      DO 2010 J=1,LLNJ
      DO 2020 K=1,6
```

```
      IP(NP,J,K)=IP(NP-1,J,K)
 2020 CONTINUE
 2010 CONTINUE
 2011 RETURN
      END
```

```
      SUBROUTINE PSTAT4
C
C        THIS SUBROUTINE UPDATES THE PIPE STATUS IF
C        TYPE 4 INTERFACE IS CREATED.
C
      COMMON IP(30,25,6),INX(30),IFACE(30),NREF(30)
      COMMON IZ,NBVOL,LOC,LL,NP,NPS,LIMIT
C
      INX(NP)=4
      IP(NP,LL+1,1)=IP(NP-1,LL+1,1)
      IP(NP,LL+1,2)=LOC
      IP(NP,LL+1,3)=IP(NP-1,LL+1,3)+NBVOL
      IP(NP,LL+1,4)=IP(NP-1,LL+1,4)
      IP(NP,LL+1,5)=IP(NP-1,LL+1,5)
      IP(NP,LL+1,6)=IP(NP,LL+1,3)-IP(NP,LL+1,2)
C        CHECK IF THE NEW PRODUCT OCCUPYS THE ENTIRE VOLUME TO THE RIGHT
      IF(IP(NP,LL+1,3).GE.LIMIT) GO TO 1051
      GO TO 1060
 1051 IP(NP,LL+1,3)=LIMIT
      IP(NP,LL+1,5)=0
      IP(NP,LL+1,6)=LIMIT-IP(NP,LL+1,2)
      NPS=LL+1
C        UPDATE THE STATUS OF ALL PRODUCTS TO THE LEFT
      GO TO 2500
C        THE FIRST PRODUCT DID NOT OCCPY THE ENTIRE VOLUME TO THE
C        RIGHT. UPDATE THE STATUS OF ALL PRODUCTS TO THE RIGHT
C        CHECKING AT THE SAME TIME IF DELIVERY POINT HAS BEEN
C        REACHED
 1060 LL2=LL+2
      NPQ=NPS
      DO 1070 J=LL2,NPQ
      NNPS=J
      IP(NP,J,1)=IP(NP-1,J,1)
      IP(NP,J,2)=IP(NP,J-1,3)
      IP(NP,J,3)=IP(NP,J,2)+IP(NP-1,J,6)
      IP(NP,J,4)=IP(NP-1,J,4)
      IP(NP,J,5)=IP(NP-1,J,5)
      IP(NP,J,5)=IP(NP,J,3)-IP(NP,J,2)
      IF(IP(NP,J,3).GE.LIMIT) GO TO 1080
      GO TO 1070
 1080 IP(NP,J,3)=LIMIT
      IP(NP,J,5)=0
      IP(NP,J,6)=LIMIT-IP(NP,J,2)
      NPS=NNPS
      GO TO 2500
 1070 CONTINUE
C        UPDATE THE STATUS OF ALL PRODUCTS TO THE LEFT
C
```

```
      2500 DO 2600 J=1,LL
           DO 2700 K=1,6
           IP(NP,J,K)=IP(NP-1,J,K)
      2700 CONTINUE
      2600 CONTINUE
           RETURN
           END
```

```
      SUBROUTINE PSTAT5
C
C        THIS SUBROUTINE UPDATES THE PIPE STATUS
C        IF TYPE 5 INTERFACE IS CREATED.
C
      COMMON IP(30,25,6),INX(30),IFACE(30),NREF(30)
      COMMON IZ,NBVOL,LOC,LL,NP,NPS,LIMIT
C
C        THE PRODUCT TO BE PUMPED IS NOT THE PRODUCT ON EITHER
C        SIDE OF INTERFACE
      INX(NP)=5
      IP(NP,LL+1,1)=IZ
      IP(NP,LL+1,2)=LOC
      IP(NP,LL+1,3)=LOC+NBVOL
      IP(NP,LL+1,4)=IP(NP-1,LL,1)
      IP(NP,LL+1,5)=IP(NP-1,LL,5)
      IP(NP,LL+1,6)=NBVOL
C        CHECK IF THE NEW PRODUCT OCCUPYS THE ENTIRE VOLUME TO THE RIGHT
      IF(IP(NP,LL+1,3).GE.LIMIT) GO TO 1053
      GO TO 1054
 1053 IP(NP,LL+1,3)=LIMIT
      IP(NP,LL+1,5)=0
      IP(NP,LL+1,6)=LIMIT-IP(NP,LL+1,2)
      NPS=LL+1
C        UPDATE THE STATUS OF ALL PRODUCTS TO THE LEFT
      GO TO 2800
C        UPDATE THE STATUS OF THE SECOND PRODUCT
 1054 IP(NP,LL+2,1)=IP(NP-1,LL+1,1)
      IP(NP,LL+2,2)=IP(NP,LL+1,3)
      IP(NP,LL+2,3)=IP(NP,LL+2,2)+IP(NP-1,LL+1,6)
      IP(NP,LL+2,4)=IZ
      IP(NP,LL+2,5)=IP(NP-1,LL+1,5)
      IP(NP,LL+2,6)=IP(NP-1,LL+1,6)
      IF(IP(NP,LL+2,3).GE.LIMIT) GO TO 1055
      GO TO 1063
 1055 IP(NP,LL+2,3)=LIMIT
      IP(NP,LL+2,6)=LIMIT-IP(NP,LL+2,2)
      NPS=LL+2
      GO TO 2800
C        THE NEW PRODUCT DID NOT OCCUPY THE ENTIRE VOLUME TO THE
C        RIGHT. UPDATE THE STATUS OF ALL PRODUCTS TO THE RIGHT
C        CHECKING AT THE SAME TIME IF THE DELIVERY POINT HAS BEEN
C        REACHED
 1063 LLM2=LL+3
      NNQ=NPS+1
      DO 1075 J=LLM2,NNQ
      NNPS=J
      IP(NP,J,1)=IP(NP-1,J-1,1)
```

```
      IP(NP,J,2)=IP(NP,J-1,3)
      IP(NP,J,3)=IP(NP,J,2)+IP(NP-1,J-1,6)
      IP(NP,J,4)=IP(NP,J-1,1)
      IP(NP,J,5)=IP(NP-1,J-1,5)
      IP(NP,J,6)=IP(NP-1,J-1,6)
      IF(IP(NP,J,3).GE.LIMIT) GO TO 1085
      GO TO 1075
 1085 IP(NP,J,3)=LIMIT
      IP(NP,J,5)=0
      IP(NP,J,6)=LIMIT-IP(NP,J,2)
      NPS=NNPS
      GO TO 2800
 1075 CONTINUE
 2800 NBR=LL-1
      IF(NBR.EQ.0) GO TO 2950
      DO 2850 J=1,NBR
      DO 2900 K=1,6
      IP(NP,J,K)=IP(NP-1,J,K)
 2900 CONTINUE
 2850 CONTINUE
 2950 IP(NP,LL,1)=IP(NP-1,LL,1)
      IP(NP,LL,2)=IP(NP-1,LL,2)
      IP(NP,LL,3)=LOC
      IP(NP,LL,4)=IP(NP-1,LL,4)
      IP(NP,LL,5)=I7
      IP(NP,LL,6)=IP(NP,LL,3)-IP(NP,LL,2)
      RETURN
      END
```

BEGINNING OF SCHEDULE NO: 1

PUMPING NO.	STATION NO.	PRODUCT NO.	VOLUME PUMPED BBLS	TYPE OF INFACE	INFACE VOL BBLS
1	5	5	900	1	400
2	5	6	1000	2	200
3	5	1	1300	3	100
4	1	1	5400	0	
5	2	1	1161	0	
6	7	5	682	0	
7	2	1	1000	0	
8	7	6	941	0	
9	3	6	1326	1	400
10	3	1	1336	3	100
11	2	1	1564	0	
12	2	3	3590	1	400
13	2	2	1429	2	200
14	6	4	2853	1	400

THE PIPE STATUS AT THE END OF LAST PUMPING:

PRODUCT SEQUENCE NO.	PRODUCT CODE NO.	BEGINING POINT BBLS	ENDING POINT BBLS	VOLUME BBLS
1	1	0	1209	1209
2	2	1209	2638	1429
3	3	2638	6228	3590
4	1	6228	11979	5751
5	6	11979	13305	1326
6	1	13305	19504	6199
7	4	19504	22357	2853
8	1	22357	31786	9429

END OF SCHEDULE: SUMMARY.

NUMBER OF PUMPINGS IN THIS PERIOD IS: 14
TOTAL NUMBER OF INTERFACES CREATED IN THIS PERIOD IS: 11.00
TOTAL INTERFACE VOLUME CREATED IN THIS PERIOD IS: 2200 BBLS
TOTAL VOLUME PUMPED IN THIS PERIOD: 24482 BBLS
RATIO OF INTERFACE VOL TO TOTAL VOL: 8.99 %

BEGINNING OF SCHEDULE NO: 2

PUMPING NO.	STATION NO.	PRODUCT NO.	VOLUME PUMPED BBLS	TYPE OF INFACE	INFACE VOL BBLS
1	5	5	1220	1	400
2	5	6	1600	2	200
3	5	1	2000	3	100
4	2	2	786	4	100
5	2	3	2790	2	200
6	2	1	1625	3	100
7	7	5	820	0	
8	2	1	189	0	
9	1	1	1221	0	
10	7	6	1056	0	
11	1	1	6159	0	
12	7	1	2532	7	400
13	6	4	2556	1	400
14	3	1	2580	0	
15	2	1	1138	0	
16	8	6	1752	1	400
17	4	1	4000	0	
18	2	1	7897	0	

THE PIPE STATUS AT THE END OF LAST PUMPING:

PRODUCT SEQUENCE NO.	PRODUCT CODE NO.	BEGINING POINT BBLS	ENDING POINT BBLS	VOLUME BBLS
1	1	0	26018	26018
2	3	26018	28808	2790
3	2	28808	31023	2215
4	3	31023	31786	763

END OF SCHEDULE: SUMMARY.

NUMBER OF PUMPINGS IN THIS PERIOD IS: 18
TOTAL NUMBER OF INTERFACES CREATED IN THIS PERIOD IS: 11.50
TOTAL INTERFACE VOLUME CREATED IN THIS PERIOD IS: 2300 BBLS
TOTAL VOLUME PUMPED IN THIS PERIOD: 41921 BBLS
RATIO OF INTERFACE VOL TO TOTAL VOL: 5.49 %

BEGINNING OF SCHEDULE NO: 3

PUMPING NO.	STATION NO.	PRODJCT NO.	VOLUME PUMPED BBLS	TYPE OF INFACE	INFACE VOL BBLS
1	5	5	954	1	400
2	5	6	1624	2	200
3	5	1	2773	3	100
4	1	1	4537	0	
5	7	5	720	7	400
6	1	1	1263	0	
7	2	1	26	0	
8	7	6	784	0	
9	2	1	2199	0	
10	7	1	1000	0	
11	3	6	1331	1	400
12	3	1	1720	3	100
13	6	4	2503	1	400
14	2	1	3072	0	
15	2	3	3882	1	400
16	2	2	513	2	200
17	8	1	1300	7	400
18	2	2	1004	4	100

THE PIPE STATUS AT THE END OF LAST PUMPING:

PRODUCT SEQUENCE NO.	PRODUCT CODE NO.	BEGINING POINT BBLS	ENDING POINT BBLS	VOLUME BBLS
1	1	0	1209	1209
2	2	1209	2726	1517
3	3	2726	6608	3882
4	1	6608	14251	7643
5	6	14251	15582	1331
6	1	15582	29275	13693
7	4	29275	31778	2503
8	1	31778	31786	8

END OF SCHEDULE: SUMMARY.

NUMBER OF PUMPINGS IN THIS PERIOD IS: 18
TOTAL NUMBER OF INTERFACES CREATED IN THIS PERIOD IS: 15.50
TOTAL INTERFACE VOLUME CREATED IN THIS PERIOD IS: 3100 BBLS
TOTAL VOLUME PUMPED IN THIS PERIOD: 31205 BBLS

RATIO OF INTERFACE VOL TO TOTAL VOL: 9.93 %

BEGINNING OF SCHEDULE NO: 4

PUMPING NO.	STATION NO.	PRODUCT NO.	VOLUME PUMPED BBLS	TYPE OF INFACE	INFACE VOL BBLS
1	5	5	1112	1	400
2	5	6	1147	2	200
3	5	1	1892	3	100
4	2	2	735	4	100
5	2	3	2468	2	200
6	2	1	1957	3	100
7	1	1	656	0	
8	7	5	834	0	
9	1	1	1129	0	
10	7	6	1135	0	
11	1	1	4045	0	
12	7	1	700	0	
13	6	4	3231	1	400
14	3	1	2381	0	
15	8	6	2372	1	400
16	2	1	1481	0	
17	4	3	1500	0	
18	2	1	4598	0	
19	4	1	4000	0	

THE PIPE STATUS AT THE END OF LAST PUMPING:

PRODUCT SEQUENCE NO.	PRODUCT CODE NO.	BEGINING POINT BBLS	ENDING POINT BBLS	VOLUME BBLS
1	1	0	21456	21456
2	3	21456	25424	3968
3	2	25424	27676	2252
4	3	27676	31558	3882
5	1	31558	31786	228

END OF SCHEDULE: SUMMARY.

NUMBER OF PUMPINGS IN THIS PERIOD IS: 19
TOTAL NUMBER OF INTERFACES CREATED IN THIS PERIOD IS: 9.50
TOTAL INTERFACE VOLUME CREATED IN THIS PERIOD IS: 1900 BBLS
TOTAL VOLUME PUMPED IN THIS PERIOD: 37373 BBLS
RATIO OF INTERFACE VOL TO TOTAL VOL: 5.08 %

BEGINNING OF SCHEDULE NO: 5

PUMPING NO.	STATION NO.	PRODJCT NO.	VOLUME PUMPED BBLS	TYPE OF INFACE	INFACE VOL BBLS
1	5	5	902	1	400
2	5	6	1198	2	200
3	5	1	2065	3	100
4	1	1	5252	0	
5	2	1	445	0	
6	7	5	661	7	400
7	2	1	1051	0	
8	7	6	932	0	
9	3	6	1270	1	400
10	3	1	1253	3	100
11	2	1	2409	0	
12	2	3	3719	1	400
13	2	2	1335	2	200
14	8	1	1163	0	
15	6	4	2630	1	400

THE PIPE STATUS AT THE END OF LAST PUMPING:

PRODUCT SEQUENCE NO.	PRODUCT CODE NO.	BEGINING POINT BBLS	ENDING POINT BBLS	VOLUME BBLS
1	1	0	1209	1209
2	2	1209	2544	1335
3	3	2544	6263	3719
4	1	6263	12776	6513
5	6	12776	14046	1270
6	1	14046	19504	5458
7	4	19504	22134	2630
8	1	22134	31786	9652

END OF SCHEDULE: SUMMARY.

NUMBER OF PUMPINGS IN THIS PERIOD IS: 15
TOTAL NUMBER OF INTERFACES CREATED IN THIS PERIOD IS: 13.00
TOTAL INTERFACE VOLUME CREATED IN THIS PERIOD IS: 2600 BBLS
TOTAL VOLUME PUMPED IN THIS PERIOD: 26285 BBLS
RATIO OF INTERFACE VOL TO TOTAL VOL: 9.89 %

BEGINNING OF SCHEDULE NO: 6

PUMPING NO.	STATION NO.	PRODUCT NO.	VOLUME PUMPED BBLS	TYPE OF INFACE	INFACE VOL BBLS
1	5	5	1198	1	400
2	5	6	1622	2	200
3	5	1	2600	3	100
4	2	2	972	4	100
5	2	3	3196	2	200
6	2	1	422	3	100
7	7	5	754	0	
8	2	1	1410	0	
9	7	1	1970	1	400
10	2	1	103	0	
11	1	1	4527	0	
12	7	1	700	1	400
13	6	4	3486	1	400
14	3	1	2314	0	
15	2	1	480	0	
16	8	6	1900	1	400
17	2	1	2909	0	
18	7	6	5000	1	400
19	2	1	3568	0	
20	4	1	1000	0	

THE PIPE STATUS AT THE END OF LAST PUMPING:

PRODUCT SEQUENCE NO.	PRODUCT CODE NO.	BEGINING POINT BBLS	ENDING POINT BBLS	VOLUME BBLS
1	1	0	17942	17942
2	3	17942	21138	3196
3	2	21138	23445	2307
4	3	23445	27164	3719
5	1	27164	29239	2075
6	6	29239	31786	2547

END OF SCHEDULE: SUMMARY.

NUMBER OF PUMPINGS IN THIS PERIOD IS: 20
TOTAL NUMBER OF INTERFACES CREATED IN THIS PERIOD IS: 15.50
TOTAL INTERFACE VOLUME CREATED IN THIS PERIOD IS: 3100 BBLS
TOTAL VOLUME PUMPED IN THIS PERIOD: 40131 BBLS

RATIO OF INTERFACE VOL TO TOTAL VOL: 7.72 %

BEGINNING OF SCHEDULE NO: 7

PUMPING NO.	STATION NO.	PRODJCT NO.	VOLUME PUMPED BBLS	TYPE OF INFACE	INFACE VOL BBLS
1	5	5	910	1	400
2	5	6	1084	2	200
3	5	1	1700	3	100
4	1	1	2000	0	
5	2	1	1650	0	
6	2	3	2522	1	400
7	7	5	630	7	400
8	2	3	504	4	100
9	2	2	1252	2	200
10	7	1	1369	0	
11	3	1	598	1	400
12	3	6	1133	2	200
13	3	1	695	2	200
14	8	1	1400	0	
15	6	4	1155	1	400

THE PIPE STATUS AT THE END OF LAST PUMPING:

PRODUCT SEQUENCE NO.	PRODUCT CODE NO.	BEGINING POINT BBLS	ENDING POINT BBLS	VOLUME BBLS
1	1	0	1209	1209
2	2	1209	2461	1252
3	3	2461	4060	1599
4	1	4060	4755	695
5	6	4755	5888	1133
6	1	5888	6486	598
7	3	6486	7913	1427
8	1	7913	19504	11591
9	4	19504	20659	1155
10	1	20659	31582	10923
11	6	31582	31786	204

END OF SCHEDULE: SUMMARY.

NUMBER OF PUMPINGS IN THIS PERIOD IS: 15
TOTAL NUMBER OF INTERFACES CREATED IN THIS PERIOD IS: 15.00
TOTAL INTERFACE VOLUME CREATED IN THIS PERIOD IS: 3000 BBLS
TOTAL VOLUME PUMPED IN THIS PERIOD: 18602 BBLS

RATIO OF INTERFACE VOL TO TOTAL VOL: 16.13 %

APPENDIX D

List of variables in the program used for testing the proposed algorithm.

Variable	Equivalent notation in the algorithm	Description
AIFR	$F_{ijk}(t)$	Production rate per hour.
AMAV	U_{ijk}	Maximum safe volume.
AMIV	L_{ijk}	Minimum safe volume.
DR	$H_{ijk}(t)$	Rate of volume reduction in a tank while a product is being pumped from it.
OFTM	T_{ijk}	Overflow time.
TEMP	T^*	Earliest overflow time.
DVOL	$v_{ijk}(t)$	Volume available for pumping.
MPD	i	Type code of a product.
LOCN	C_k	Location of a station.
APR	G_{ijk}	Pumping rate.
NREF	$\hat{k}_n$	Station number from which a product is pumped, during nth pumping.
NSTNS	K	Total number of stations.
APTM	τ	Minimum allowable pumping duration.
PTM	T^n_{ijk}	Pumping duration.
BVOL	V^n_{ijk}	Volume of product pumped.
INV	$P_{ijk}(t)$	Volume of a product in its tank at any time t.
NP	n	Pumping sequence number.
		After NPth pumping, the six attributes of the Mth product in the pipeline are denoted as follows:

Variable	Equivalent notation in the algorithm	Description
IP(NP,M,1)	X_m	Type code.
IP(NP,M,2)	B_m	Beginning co-ordinate.
IP(NP,M,3)	E_m	Ending co-ordinate.
IP(NP,M,4)	X_{m-1}	Type code of (M-1)-th product.
IP(NP,M,5)	X_{m+1}	Type code of (M+1)-th product.
IP(NP,M,6)		Volume of product.
LIMIT		Termination point of the pipeline.
NSHDL		Number of schedules to be generated.
NOSDL		Schedule number.
NPS		Number of products in the pipeline.
IFACE		Total interface volume in the pipeline.
FCNT		Additional number of interfaces created.
ITOTV		Total volume of products pumped.
IADD		Additional interface volume created after a pumping.
NOIF		Total number of interfaces present in the pipeline.
INX		Type of interface created.
RATIO		Ratio of interface volume to total volume.

APPENDIX E

Flow chart of the program used for testing the proposed algorithm.

(For detailed flow charts of interface counter, print statements and all subroutines refer to APPENDIX B)

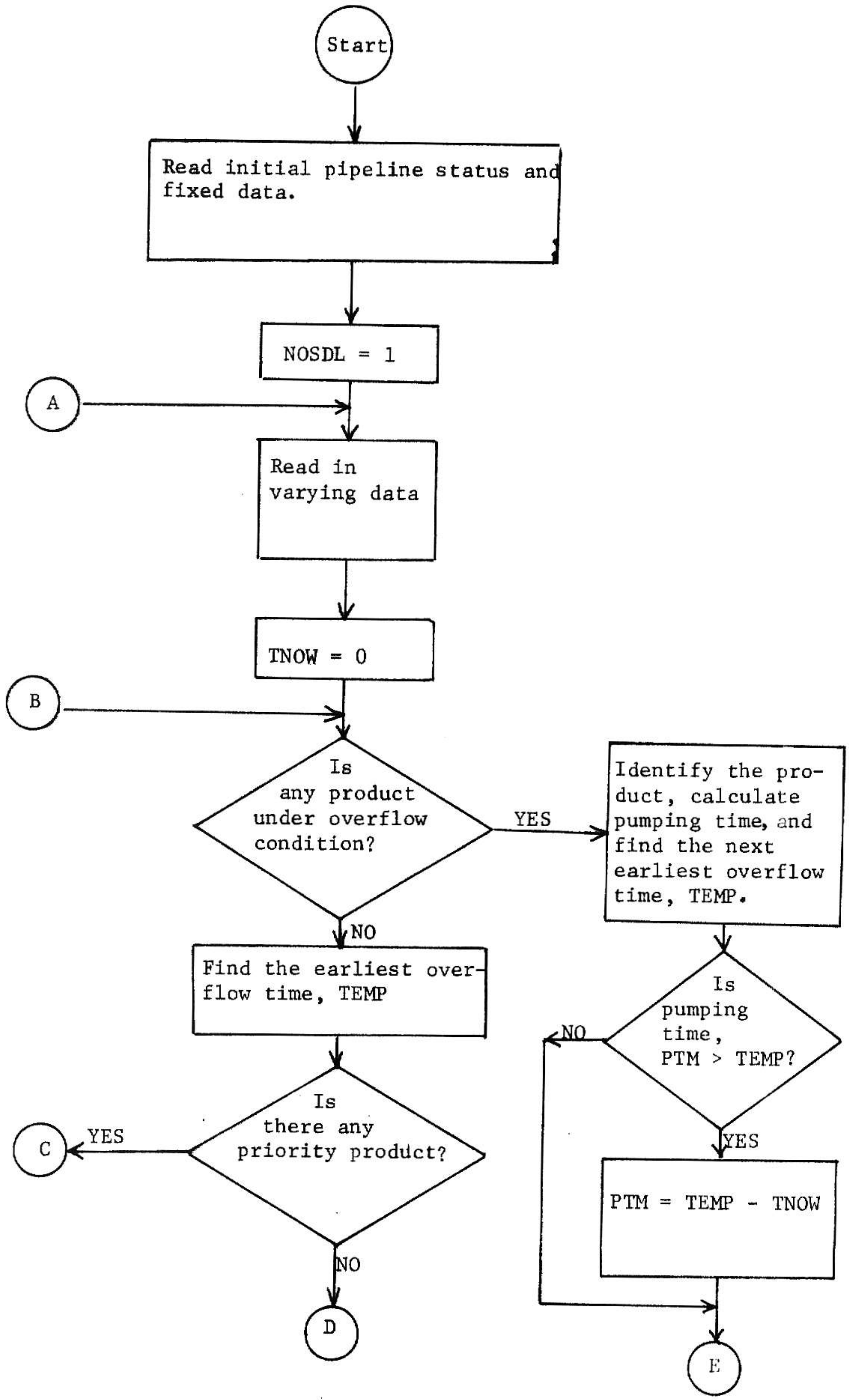

Fig. E.1. Main Program

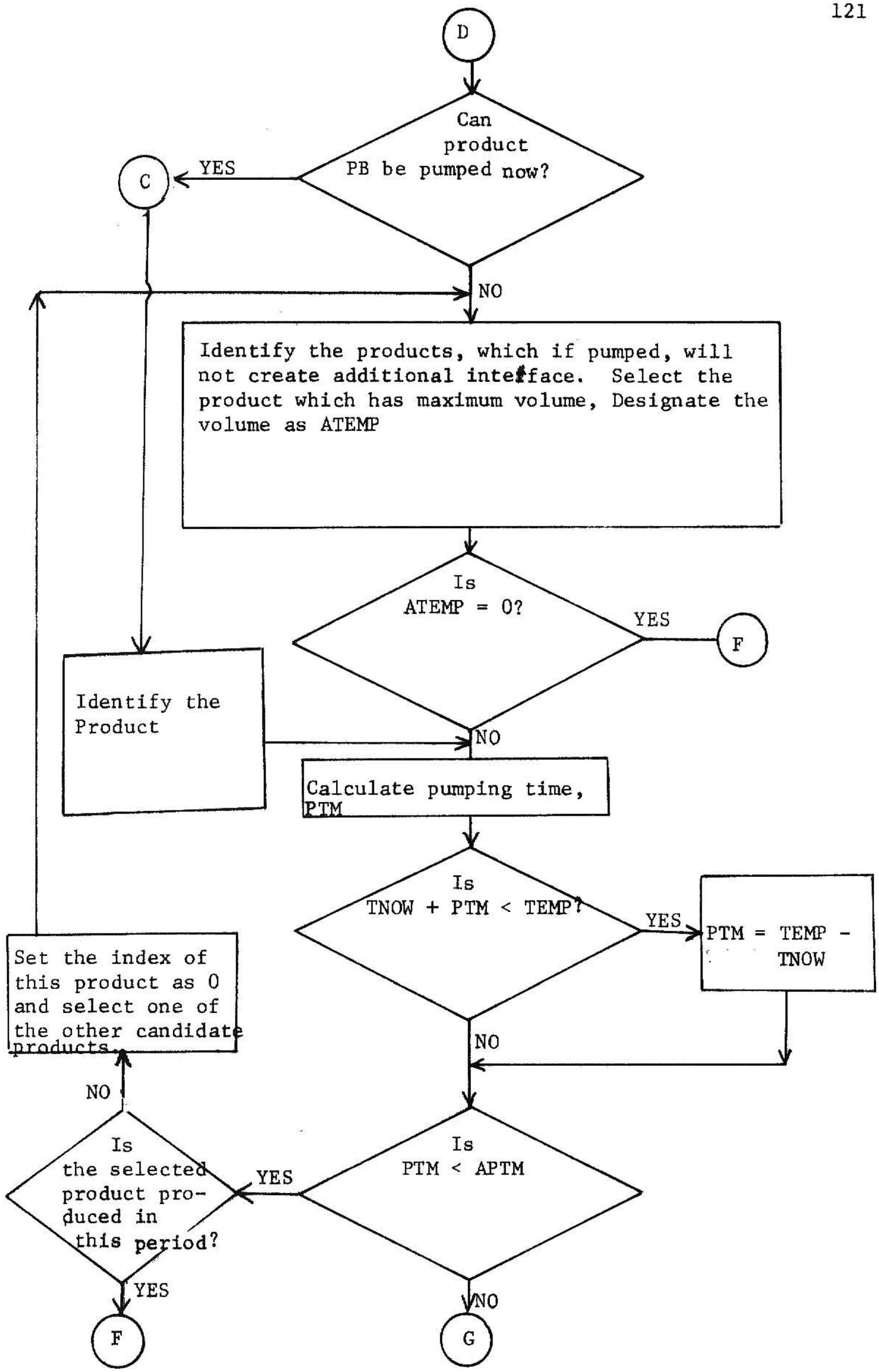

Fig. E.1. Main Program (continued)

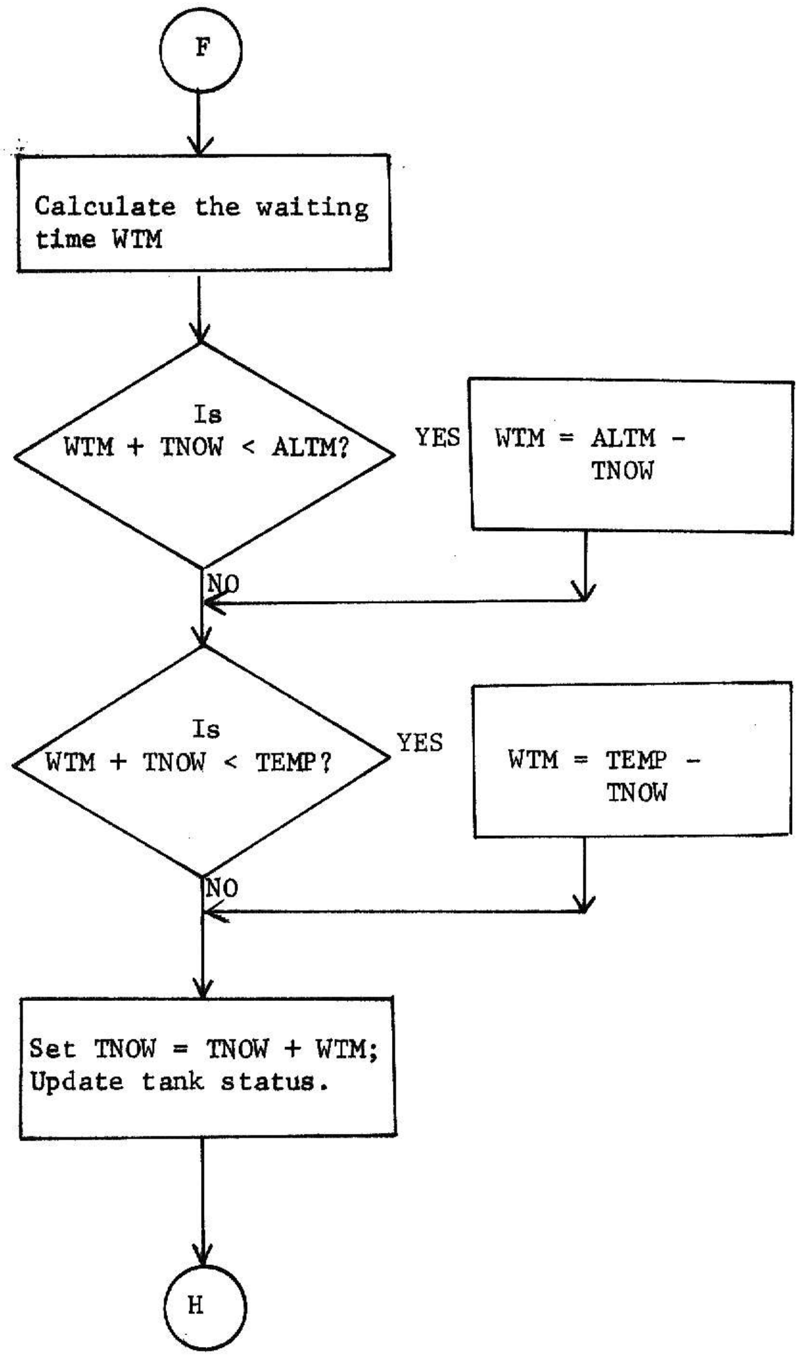

Fig. E.1. Main Program (continued)

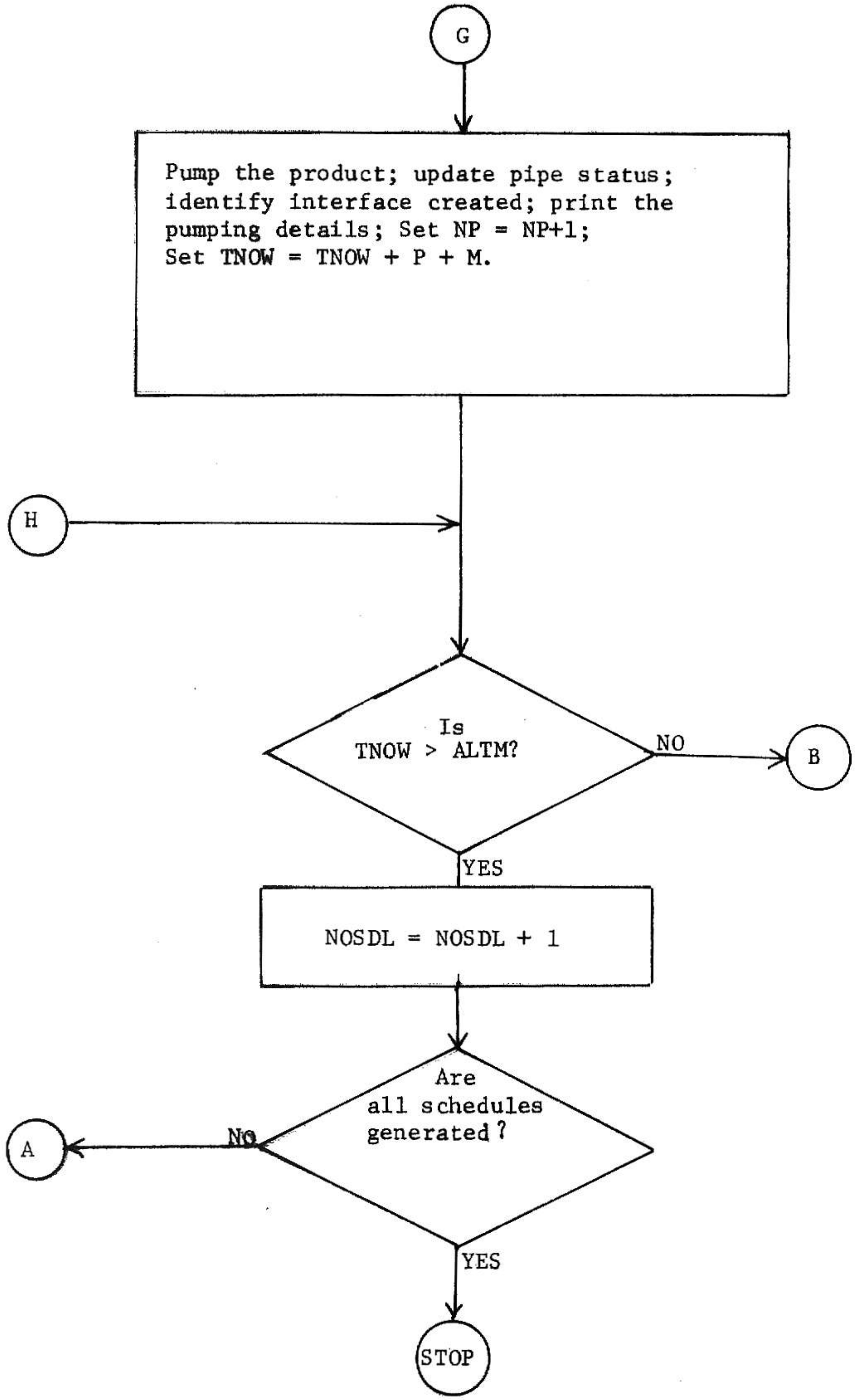

Fig. E.1. Main Program (continued)

APPENDIX F

The program used for testing the proposed algorithm.

ILLEGIBLE DOCUMENT

THE FOLLOWING DOCUMENT(S) IS OF POOR LEGIBILITY IN THE ORIGINAL

THIS IS THE BEST COPY AVAILABLE

```
C
C
C
C         SCHEDULING OF GAS PRODUCTS THROUGH A MULI-PRODUCT
C         PIPELINE SYSTEM.
C
C
C
C         THIS PROGRAM WAS WRITTEN TO TEST AN ALGORITHM
C         DEVELOPED FOR SCHEDULING GAS PRODUCTS THROUGH A
C         MULTI-PRODUCT PIPELINE SYSTEM SUCH THAT THE INTERFAC
C         CREATED IS MINIMUM.SCHEDULES ARE GENERATED FOR SIX
C         SUCCESSIVE PRODUCTION PERIODS OF THE GAS PLANTS
C         ASSOCIATED WITH THE PIPELINE SYSTEM. THIS PROGRAM
C         CAN HOWEVER,BE ADOPTED EASILY TO GENERATE ONLY ONE
C         SCHEDULE FOR A PRODUCTION PERIOD.
C
C
      COMMON IP(200,25,6),INX(200)
      COMMON IZ,NBVOL,LOC,LL,NP,NPS,LIMIT
      DIMENSION AIFF(10,10),AMAV(10,10),AMIV(10,10),DR(10,10)
      DIMENSION AINV(10,10),NOP(10),LOCN(10),NPROD(10)
      DIMENSION OFTM(10,10),DVOL(10,10),MPD(10,10),IFACT(200)
      DIMENSION DIFF(10,10),APR(10,10),NO(200)
      DIMENSION NREF(200),IND(10,10)
C
C
C         INITIALIZE THE INPUT OUTPUT UNITS CODES.
C
C         NCRDR IS CARD READER AND NPRNT IS THE PRINTER.
      NCRDR=1
      NPRNT=3
C
C
C         TYPE OF OUTPUT.
C
C         IF NPARM=1, WHETHER JPARM=0 OR 1, SCHEDULE DETAILS
C         WILL BE PRINTED OUT IN TABULAR FORM.
C
C         IF NPARM=0, JPARM SHOULD HAVE A VALUE EITHER 0 OR 1.
C         IF JPARM=0, PIPE STATUS WILL BE PRINTED OUT AFTER
C         EVERY 5 PUMPINGS. IF JPARM=1, PIPE STATUS WILL
C         BE PRINTED OUT AFTER EVERY PUMPINGS.
C         NOTE: WHEN NPARM=0, PIPE STATUS WILL BE PRINTED OUT
C         IN VECTOR FORM.
C
      NPARM=1
      JPARM=0
```

```
C
C         FORMAT STATEMENTS.
C
   45 FORMAT(6I10)
   46 FORMAT(5F10.2)
 3358 FORMAT('1',5X,'BEGINNING OF SCHEDULE NO:',I3)
   50 FORMAT('0',5X,'TANK STATUS AT THE BEGINNING OF SCHEDULE:')
 3665 FORMAT('0',5X,'STATION',4X,'TANK NO.',4X,'MAXI VOL',4X,'MIN VOL',
     14X,'INTL VOL',5X,'PROD RATE',4X,'OVFLO TIME',/' ',30X,'BLS',
     28X,'BBLS',7X,'BBLS',7X,'BBLS/DAY',9X,'HRS',/)
 3667 FORMAT(' ',5X,I4,8X,I4,7X,F8.2,4X,F7.2,4X,F8.2,6X,F7.2,3X,F9.2)
   63 FORMAT('0',5X,'MINIMUM ALLOWABLE PUMPING TIME:',F8.2,' MINUTES.')
 8600 FORMAT(' ',5X,'THE PRODUCTION PERIOD IS:',F8.2,' HOURS')
  476 FORMAT('1',30X,'THE DETAILS OF THE SCHEDULE ARE:')
  478 FORMAT('0',4X,'PUMPING',3X,'STATION',3X,'PRODUCT',3X,'STARTING',
     13X,'FINISHING',3X,'VOLUME',3X,'TYPE OF',3X,'INFACE',5X,'WAITING',/
     2' ',6X,'NO',2(8X,'NO'),8X,'TIME',7X,'TIME',6X,'PUMPED',4X,'INFACE'
     3,4X,'VOL',6X,'TIME',/' ',36X,'HOURS',6X,'HOURS',6X,'BBLS',15X,'BBL
     4S',4X,'HOURS',/)
  110 FORMAT('0','ERROR:TWO TANKS ABOUT TO OVERFLOW AT THE SAME TIME')
  116 FORMAT ('0',5X,'ERROR:PUMPING TIME IS EQUAL TO OR LESS THAN 0')
 3010 FORMAT('0',5X,'ERROR:THE VOLUME OF PRODUCT IN TANK NO',I2,'AT STAT
     1ION NO',I2,/' ','EXCEEDS SAFE MAXIMUM. THE VOLUME IS:',F8.2)
  139 FORMAT(' ',5X,'TOTAL WAITING TIME IS: ',F6.2,' HOURS')
  146 FORMAT(' ',85X,F7.2)
 3040 FORMAT('0',5X,'ERROR: THE VOLUME IN TANK NO',I2,'STATION NO',I2,
     1'IS BELOW SAFE',/' ','MINIMUM.THE VOLUME IS',F8.2)
 3360 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.1')
 3380 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.2')
 3400 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.3')
 3420 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.5')
 3440 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.6')
 3460 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.7')
 3454 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.4')
 3458 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.9')
 3470 FORMAT('0',5X,'PUMPING OCCURED AT STATION NO.8')
 3510 FORMAT(' ',5X,'VOLUME PUMPED:',I10)
 9200 FORMAT('+',35X,'(BVOL=',F12.5,' )')
 3511 FORMAT(' ',5X,'THE PRODUCT PUMPED:',I3)
 3472 FORMAT(' ',5X,'TIME AT THE START OF PUMPING IS:',F12.5)
 3473 FORMAT(' ',5X,'NO.OF HOURS THE PRODUCT IS PUMPED:',F12.5)
 3512 FORMAT(' ',5X,'VOLUME IN THIS TANK AT THE END OF PUMPING:',F12.5)
 3513 FORMAT(' ',5X,'MAXIMUM VOLUME IN THIS TANK:',F12.5)
 3514 FORMAT(' ',5X,'MINIMUM VOLUME IN THIS TANK:',F12.5)
 3515 FORMAT(' ',5X,'PUMPING OCCURED AT OVERFLOW CONDITION')
 3520 FORMAT('0',5X,'THE PIPE STATUS AT THE END OF LAST PUMPING:')
 3521 FORMAT('0',5X,'PRODUCT SEQUENCE NO:',I2)
 3550 FORMAT(' ',5X,'IP(',I3,',',I2,',',I2,')=',I10)
```

```
 3570 FORMAT('0',5X,'TYPE OF INTERFACE CREATED:',I3)
 3575 FORMAT(' ',5X,'NO.OF INTERFACES THIS STEP:',I3)
 3580 FORMAT(' ',5X,'ADDITIONAL INTERFACE VOLUME DUE TO LAST PUMPING:',
     1I8,' BBLS')
 3590 FORMAT(' ',5X,'TOTAL INTERFACE SO FAR:',I6,' BBLS')
 3576 FORMAT(' ',5X,'INTERFACE VOLUME AT THE BEGINNING OF SCHEDULE:',
     1I8,' BBLS')
 3597 FORMAT(' ',5X,'TOTAL VOLUME PUMPED SO FAR:',I8,' BBLS')
 3705 FORMAT(' ',6X,I3,2(8X,I2),6X,F6.2,5X,F6.2,6X,I4,6X,I2)
 3710 FORMAT('+',78X,I3)
 3555 FORMAT('0',5X,'PRODUCT',5X,'PRODUCT',4X,'BEGINING',4X,'ENDING',
     14X,'VOLUME',/' ',5X,'SEQUENCE',6X,'CODE',7X,'POINT',6X,'POINT',
     223X,'BBLS',/' ',8X,'NO.',9X,'NO.',8X,'BBLS',7X,'BBLS',/)
 3556 FORMAT(' ',8X,I2,10X,I2,7X,I6,5X,I6,4X,I6)
 3600 FORMAT('-',5X,'END OF SCHEDULE: SUMMARY.')
 3610 FORMAT('0',5X,'NUMBER OF PUMPINGS IN THIS PERIOD IS:',I3)
 3620 FORMAT(' ',5X,'TOTAL NUMBER OF INTERFACES CREATED IN THIS PERIOD
     1IS:',F6.2)
 3630 FORMAT(' ',5X,'TOTAL INTERFACE VOLUME CREATED IN THIS PERIOD IS:'
     1,I8,' BBLS')
 3631 FORMAT(' ',5X,'TOTAL VOLUME PUMPED IN THIS PERIOD:',I8,' BBLS')
 3635 FORMAT(' ',5X,'THE SCHEDULE PERIOD IS:',F7.2,2X,'HOURS')
 3636 FORMAT(' ',5X,'TOTAL IDLE PERIOD OF PIPELINE DURING SCHEDULE:',
     1F6.2,' HOURS')
 3640 FORMAT(' ',5X,'RATIO OF INTERFACE VOL TO TOTAL VOL:',F6.2,' %')
 3685 FORMAT('0',5X,'INTERFACE VOLUME AT THE START OF NEXT SCHEDULE:',
     1I6,' BBLS')
C
C          READ IN, THE DETAILS OF PUMP STATIONS AND GAS PLANTS,
C          WHICH ARE NOT CHANGED FROM PERIOD TO PERIOD.
C
C          EXPLANATION OF VARIABLES:
C
C          NSTNS: NUMBER OF PUMP STATIONS IN THE SYSTEM.
C          LIMIT:TERMINATION POINT, IN BBLS OF THE PIPELINE.
C          NSHDL: NUMBER OF SCHEDULES TO BE GENERATED.
C          NOP(I): NUMBER OF PRODUCTS STORED AT STATION I.
C          LOCN(I): LOCATION, IN TERMS OF BARRELS ,OF STATION I.
C          NPD(I,J): TYPE CODE OF PRODUCT STORED IN TANK J, AT STATION I.
C          APR(I,J): PUMPING RATE OF THE PUMP ATTACHED TO TANK J,AT STATION
C          AMAV(I,J): MAXIMUM SAFE VOLUME OF TANK J, AT STATION I.
C          AMIV(I,J): MINIMUM SAFE VOLUME OF TANK J, AT STATION I.
C          NOTE: ALL VOLUMES ARE IN BBLS;THE PUMPING RATE IS BBLS/HR.
C
      READ (NCRDR,45) NSTNS,LIMIT,NSHDL
      DO 25 I=1,NSTNS
      READ(NCRDR,45) NOP(I),LOCN(I)
      NN1=NOP(I)
```

```
      READ(NCRDR,45) (MPD(I,J),J=1,NN1)
      READ(NCRDR,46) (APR(I,J),J=1,NN1)
      READ(NCRDR,46) (AMAV(I,J),J=1,NN1)
      READ(NCRDR,46) (AMIV(I,J),J=1,NN1)
   25 CONTINUE
C
C
C          APTM: MINIMUM ALLOWABLE PUMPING TIME,IN MINUTES.
C          ALP4: LIMITING PERCENTAGE VOUME OF MAXIMUM VOLUME OF
C          PL STORAGE TANK AT STATION NO.5.
C
      APTM=30.0
      ALP4=0.90
C
C          NOW READ IN THE DETAILS REQUIRED BEFORE EACH SCHEDULE
C          IS GENERATED
C
C          NPS: NUMBER OF PRODUCTS IN THE PIPE LINE
C          THE INITIAL STATUS OF PIPELINE IS READ IN AS FOLLOWS:
C          FOR PRODUCT J IN THE PIPELINE,
C          IP(1,J,1)= TYPE CODE
C          IP(1,J,2)= STARTING CO-ORDINATE IN TERMS OF BBLS
C          IP(1,J,3)= ENDING CO-ORDINATE IN TERMS OF BBLS
C          IP(1,J,4)= TYPE CODE OF J-1TH PRODUCT
C          IP(1,J,5)= TYPE CODE OF J+1TH PRODUCT
C          IP(1,J,6)= VOLUME IN BBLS
C          NOTE: J=1,2,.........,NPS
C
      DO 26 I=1,NSTNS
      K1=NOP(I)
      READ(NCRDR,46) (AINV(I,J),J=1,K1)
   26 CONTINUE
      READ(NCRDR,45) NPS
      DO 24 J=1,NPS
      READ(NCRDR,45) (IP(1,J,K),K=1,6)
   24 CONTINUE
      READ(NCRDR,45) IFACE(1)
C
C          NOSDL: SCHEDULE NO.
C          NREF(1): STATION FROM WHICH A PRODUCT WAS PUMPED DURING
C          ZERO-TH PUMPING
C          INX(1): TYPE OF INTERFACE CREATED  AFTER ZERO-TH PUMPING
C          ALTM: PRODUCTION PERIOD IN HOURS.
C          DIFR(I,J): INPUT IN BBLS/DAY TO TANK J,AT STATION I.
C          DR(I,J): THE REDUCTION RATE OF VOLUME IN BBLS/HR,
C          WHEN PRODUCT IN TANK J,AT STATION I IS PUMPED.
C          AIFR(I,J): INPUT RATE TO TANK J,AT STATION I, IN BBLS/HR.
C          OFTM(I,J): OVERFLOW TIME IN HRS FOR TANK J,AT STATION I.
```

```
      C
            NOSDL=1
            NREF(1)=0
            INX(1)=0
      C
      C        WHEN MORE THAN ONE SCHEDULE IS GENERATED AT A
      C        TIME,AFTER EACH SCHEDULE THE PROGRAM CONTINUES FROM
      C        STATEMENT NO.47.
      C
         47 READ(NCRDR,46) ALTM
            DO 30 I=1,NSTNS
            NN1=NOP(I)
            READ (NCRDR,46) (DIFR(I,J),J=1,NN1)
         30 CONTINUE
      C
      C        NO OTHER DATA IS READ IN AFTER THIS STATEMENT.
      C
      C        IND(I,J): INDEX TO INDICATE WHETHER PRODUCT IN TANK J,
      C        AT STATION I IS AVAILABLE FOR PUMPING. IF IND(I,J)=1,
      C        THE PRODUCT IS AVAILABLE;IF IT IS EQUAL TO 0 THE PRODUCT IS
      C        NOT AVAILABLE.
      C
            DO 70 I=1,NSTNS
            NN5=NOP(I)
            DO 71 J=1,NN5
            IND(I,J)=1
            AIFR(I,J)=DIFR(I,J)/24.0
            DR(I,J)=APR(I,J)-AIFR(I,J)
            IF(DIFR(I,J).EQ.0.0) GO TO 52
            CFTM(I,J)=(AMAV(I,J)-AINV(I,J))/AIFR(I,J)
            GO TO 71
         52 CFTM(I,J)=99999.00
         71 CONTINUE
         70 CONTINUE
      C        HPTM:MINIMUM ALLOWABLE PUMPING TIME IN HOURS.
        770 HPTM=APTM/60.0
      C
      C        THE FOLLOWING STATEMENTS, TILL STATEMENT NO.46 SHOULD BE OMITTED
      C        IF TANK STATUS IS INITIALIZED AFTER EVERY SCHEDUL .
      C
            IF(NOSDL.EQ.2) GO TO 41
            IF(NOSDL.EQ.4) GO TO 42
            IF(NOSDL.EQ.5) GO TO 43
            IF(NOSDL.EQ.6) GO TO 48
            GO TO 44
         41 AINV(4,1)=7400.00
            GO TO 44
         42 AINV(4,1)=7400.00
```

```
      AINV(4,2)=3200.00
      GO TO 44
   43 AINV(4,1)=10400.00
      AINV(9,1)=5500.00
      GO TO 44
   48 AINV(4,2)=3600.00
C         PRINT SCHEDULE NO.,TANK STATUS,MINIMUM PUMPING TIME
C         AND PRODUCTION PERIOD.
   44 WRITE(NPRNT,3358) NOSDL
      WRITE (NPRNT,50)
      WRITE (NPRNT,3668)
      DO 60 I=1,NSTNS
      NM=NOP(I)
      DO 62 J=1,NM
      WRITE(NPRNT,3667) I,J,AMAV(I,J),AMIV(I,J),AINV(I,J),MIP (I,J),
     1CFTM(I,J)
   62 CONTINUE
   60 CONTINUE
      WRITE(NPRNT,63) APTM
      WRITE(NPRNT,8600) ALTM
 9000 IF(NPARM.EQ.0) GO TO 65
C
C         PRINT THE TITLES OF PRINT OUT
C
      WRITE (NPRNT,476)
      WRITE(NPRNT,478)
C
C         TNOW: PRESENT TIME.
C         NP: PUMPING SEQUENCE NO.
C         FCNT: TOTAL NUMBER OF INTERFACES CREATED IN A SCHEDUL .
C         ITOTV: TOTAL VOLUME OF PRODUCTS PUMPED IN A SCHEDULE.
C         NPAUS: NUMBER OF IDLE PERIODS BEFORE A PUMPING.
C         WTM: WAITNG PERIOD OR IDLE PERIOD.
C         NO(1): THIS IS EQUIVALENT TO BETA IN THE
C         ALGORITHM.
C         TTPS: TOTAL IDLE PERIOD IN SCHEDULE.
C
   65 TNOW=0.0
      NP=2
      FCNT=0.0
      ITOTV=0
      NPAUS=0
      WTM=0.0
      NO(1)=0
      TTPS=0.0
C
C
C         AT TNOW CHECK IF ANY TANK IS ABOUT TO OVERFLOW.
```

```
C          IF THERE IS ONE SCHEDULE IT WITH PUMPING TIME
C          EQUAL TO MINIMUM OF TIME TAKEN TO REACH BOTTOM SAFE
C          LEVEL AND DIFFERENCE IN TIME BETWEEN TNOW AND NEXT
C          OVERFLOW TIME.
C
C
   90 NO(NP)=0
      DO 85 J=1,NSTNS
      NPROD(J)=0
   85 CONTINUE
      II=0
      JJ=0
      DO 100 I=1,NSTNS
      K1=NOP(I)
      DO 105 J=1,K1
      IF(OFTM(I,J).NE.TNOW) GO TO 105
      NO(NP)=NO(NP)+1
      II=I
      JJ=J
  105 CONTINUE
  100 CONTINUE
C
C          FIND THE EARLIEST OVERFLOW TIME
C
      TEMP=99999.00
      DO 120 I=1,NSTNS
      K1=NOP(I)
      DO 125 J=1,K1
      IF((I.EQ.II).AND.(J.EQ.JJ)) GO TO 125
      IF(OFTM(I,J).LE.TEMP) GO TO 130
      GO TO 125
  130 TEMP=OFTM(I,J)
  125 CONTINUE
  120 CONTINUE
      IF(NO(NP).EQ.0) GO TO 300
C          IF TWO TANKS ARE ABOUT TO OVERFLOW AT THE SAME
C          TIME REPORT AN ERROR AND STOP.
      IF(NO(NP).GE.2) GO TO 101
      GO TO 115
  101 WRITE(NPRNT,110)
      GO TO 6000
C
C          AS NO PRODUCT IS ABOUT TO OVERFLOW, CHECK
C          FOR PRIORITY PRODUCT,PRODUCT PR,AND IF THESE
C          CAN NOT BE PUMPED TRY TO PUMP A PRODUCT WHICH, IF PUMPED
C          WILL NOT CREATE ADDITIONAL INTERFACE. HOWEVER, FIRST
C          SCAN THE PIPE STATUS AND IDENTIFY THE PRODUCT
C          IN FRONT OF EACH STATION.
```

```
C
  300 DO 305 I=1,NSTNS
      DO 310 J=1,NPS
      IF((IP(NP-1,J,2).LT.LOCN(I)).AND.(IP(NP-1,J,3).GT.LOCN(I)))GO TO
     1308
      GO TO 310
C         AVOID MAKING TYPE 7 INTERFACE
  308 IF(I.EQ.1) GO TO 309
      IF((IP(NP-1,J,2).GT.(LOCN(I)-200)).OR.(IP(NP-1,J,3).LT.(LOCN(I)+20
     10))) GO TO 305
  309 NPROD(I)=IP(NP-1,J,1)
      GO TO 305
  310 CONTINUE
  305 CONTINUE
C
C         IF TWO DIFFERENT PRODUCTS FOLLOW ONE ANOTHER FROM
C         THE SAME STATION THE INTERFACE CREATED IS ONLY
C         ONE. THEREFORE IF PREVICUS PUMPING OCCURED AT OVER
C         FLOW CONDITION SCHEDULE THE PRODUCT FROM THE NEXT
C         TANK IN THE SAME STATION IMMEDIATELY.
C         THIS PRODUCT IS KNOWN AS PRIORITY PRODUCT.
C
 1055 IF(NO(NP-1).EQ.1) GO TO 327
C
C         AS IT IS REQUIRED THAT PB SHOULD ALWAYS BE FOLLOWED
C         AND PRECEEDED BY K, ARBITRARILY IF PB VOLUME IN ITS
C         TANK IS ABOVE ALP4 TIMES ITS MAXIMUM,AND
C         IF K IS IN THE PIPE IN FRONT OF GOLDSBY PUMP PB
C         FROM GOLDSBY.
C
  315 IF((AINV(6,1).GE.(ALP4*3600.0)).AND.(NPROD(6).EQ.1)) GO TO 326
C
C         SELECT THE PRODUCT WHICH,IF PUMPED, WOULD NOT CREATE
C         ADDITIONAL INTERFACE. IF THERE ARE MORE THAN ONE
C         CANDITATE PRODUCTS, SELECT ONE WITH MAXIMUM VOLUME.
C
C         DVOL(I,J): VOLUME OF PRODUCT , IN TANK J, AT STATION
C         I AVAILABLE FOR PUMPING.
C
 8500 DO 316 I=1,NSTNS
      K1=NOP(I)
      DO 317 J=1,K1
      DVOL(I,J)=AINV(I,J)-AMIV(I,J)
  317 CONTINUE
  316 CONTINUE
 8510 ATEMP=0.0
      DO 325 I=1,NSTNS
      K1=NOP(I)
```

```
      DO 330 J=1,K1
      IF((DVOL(I,J).LE.6.0).AND.(DIFR(I,J).EQ.0.0)) GO TO 330
      IF(IND(I,J).EQ.0) GO TO 330
      IF(MPD(I,J).EQ.NPROD(I)) GO TO 345
      GO TO 330
  345 IF (DVOL(I,J).GE.ATEMP) GO TO 350
      GO TO 330
  350 II=I
      JJ=J
      ATEMP=DVOL(I,J)
      GO TO 325
  330 CONTINUE
  325 CONTINUE
C        IF THE VOLUME OF THE ONLY PRODUCT THAT CAN BE PUMPED
C        NOW IS LESS THAN 6 BBLS,WAIT TILL SOME PRODUCT IS ABOUT TO
C        OVERFLOW. HOWEVER, IF THE SELECTED PRODUCT IS NOT
C        PRODUCED IN THIS PERIOD, CHOOSE SOME OTHER PRODUCT BY
C        SETTING THE AVAILABILITY INDEX , IND(I,J) OF
C        ALREADY SELECTED PRODUCT EQUAL TO 0.
 9300 IF(ATEMP.LE.6.0) GO TO 8900
      GO TO 115
 8900 IF((II.EQ.0).AND.(JJ.EQ.0)) GO TO 8901
      IF(DIFR(II,JJ).EQ.0.0) GO TO 8650
 8901 WTM=TEMP-TNOW
      IF((TNOW+WTM).GE.ALTM) WTM=ALTM-TNOW
      GO TO 8700
 8650 IND(II,JJ)=0
      II=0
      JJ=0
      GO TO 8510
C
C        PRODUCT PR IS SELECTED.
C
  326 II=6
      JJ=1
      GO TO 115
C
C        PRIORITY PRODUCT IS SELECTED.
C
  327 DO 328 I=1,NSTNS
      K1=NOP(I)
      DO 329 J=1,K1
      IF((LOCN(I).EQ.LOC).AND.(MPD(I,J).EQ.IZ))GO TO 331
      GO TO 329
  331 II=I
      JJ=J+1
      GO TO 332
  329 CONTINUE
```

```
  328 CONTINUE
  332 IF(JJ.GT.NOP(II)) JJ=JJ-2
      IF((MPD(II,JJ).EQ.1).OR.(JJ.EQ.0)) GO TO 333
C        DO NOT PUMP THE PRIORITY PRODUCT IF IT IS NOT
C        PRODUCED IN THIS PERIOD.
      IF(DIFR(II,JJ).EQ.0.0) GO TO 333
      GO TO 115
  333 II=0
      JJ=0
      GO TO 315
C
C
C        CALCULATE PUMPING TIMES
C
C
  115 PTM=(AINV(II,JJ)-(AMIV(II,JJ)+5.0)) /PR(II,JJ)
C        IF CALCULATED PUMPING TIME IS LESS
C        THAN OR EQUAL TO 0 REPORT AN ERROR AND STOP.
      IF(PTM.LE.0.0) GO TO 118
      GO TO 117
  118 WRITE(NPRNT,116)
      GO TO 6000
  117 IF((TNOW+PTM).GT.ALTM) PTM=ALTM-TNOW
      IF((TNOW+PTM).GT.TEMP) PTM=TEMP-TNOW
C
C        IF THE PUMPING TIME IS LESS THAN APTM DO NOT
C        PUMP THE PRODUCT. CALCULATE THE WAITNG TIME (TH-
C        IDLE PERIOD OF PIPELINE), UPDATE THE TANK STATUS
C        AND GO BACK TO STATEMENT NO.90. HOWEVER, IF THE
C        PRODUCT SELECTED IS NOT PRODUCED, CHOOSE ONE OF TH
C        OTHER CANDIDATE PRODUCTS.
C
  132 IF((NO(NP).EQ.0).AND.(PTM.LT.HPTM)) GO TO 133
      GO TO 134
  133 IF(DIFR(II,JJ).EQ.0.0) GO TO 8650
      WTM=(APR(II,JJ)*HPTM)/AIFR(II,JJ)
      IF((TNOW+WTM).GT.ALTM) WTM=ALTM-TNOW
      IF((TNOW+WTM).GT.TEMP)WTM=TEMP-TNOW
 8700 DO 136 I=1,NSTNS
      K1=NOP(I)
      DO 137 J=1,K1
      IF(DIFR(I,J).EQ.0.0) GO TO 137
      AINV(I,J)=AINV(I,J)+AIFR(I,J)*WTM
C        IF UPDATED VOLUME IS 5 BBLS GREATER  THAN MAXIMUM
C        REPORT AN ERROR AND STOP.
      IF(AINV(I,J).GE.(AMAV(I,J)+5.0)) GO TO 5000
      GO TO 137
 5000 WRITE(NPRNT,5010) I,J,AINV(I,J)
```

```
      GO TO 6000
  137 CONTINUE
  136 CONTINUE
      NPAUS=NPAUS+1
      TNOW=TNOW+WTM
      IF (TNOW.GE.AITM) GO TO 3598
      GO TO 90
C
  134 IF (NPAUS.EQ.0) GO TO 142
      IF (NPARM.EQ.1) GO TO 141
      WRITE(NPRNT,139) WTM
      GO TO 531
  141 WRITE(NPRNT,146) WTM
  531 TTPS=TTPS+WTM
  142 BVOL=PTM*APR(II,JJ)
      NBVOL=BVOL
      LOC=LOCN(II)
      IZ=MPE(II,JJ)
C
C         CALCULATE THE NEW INITIAL VOLUME OF THIS TANK
C         AND ITS OVERFLOW TIME.
C
 5010 AINV(II,JJ)=AINV(II,JJ)-BVOL+PTM*AIFR(II,JJ)
C         IF UPDATED VOLUME IS 5 BBLS LESS THAN MINIMUM SAFE VOLUM
C         REPORT AN ERROR AND STOP.
      IF(AINV(II,JJ).LE.(AMIV(II,JJ)-5.0)) GO TO 5020
      GO TO 5030
 5020 WRITE(NPRNT,5040) II,JJ,AINV(II,JJ)
      GO TO 6000
 5030 IF(DIFR(II,JJ).EQ.0.0) GO TO 143
      OFTM(II,JJ)=TNOW+PTM+(AMAV(II,JJ)-AINV(II,JJ))/AIFR(II,JJ)
C
C         UPDATE THE VOLUME IN ALL THE OTHER TANKS.
C
  143 DO 135 I=1,NSTNS
      K1=NOP(I)
      DO 140 J=1,K1
      IF((I.EQ.II).AND.(J.EQ.JJ)) GO TO 140
      IF(DIFR(I,J).EQ.0.0) GO TO 140
      AINV(I,J)=AINV(I,J)+AIFR(I,J)*PTM
      IF(AINV(I,J).GE.(AMAV(I,J)+5.0)) GO TO 5050
      GO TO 140
 5050 WRITE(NPRNT,5010) I,J,AINV(I,J)
      GO TO 6000
  140 CONTINUE
  135 CONTINUE
      NPAUS=0
      WTM=0.0
```

```
C         FROM THE VALUE OF II LOCATE THE REFINERY.
  450 NREF(NP)=II
C
C
C         UPDATE THE PIPE STATUS.
C
C
C         IZ IS THE PRODUCT INDEX THAT IS TRANSMITTED FROM
C         MAIN PART
C         LOC IS THE LOCATION TRANSMITTED
C         NP IS THE PUMPING SEQUENCE NO
C         NBVOL IS THE VOLUME TO BE PUMPED.
C
C         SINCE THE TYPE OF PRODUCT IN THE PIPE AT THE PUMPING
C         LOCATION IS NOT STORED SEPARATELY FIRST FIND THE PRODUCT
C         IF WE HAVE AN INTERFACE GO STATEMENT 1000
C
  500 DO 501 K=1,NPS
      LL=K
      IF(IP(NP-1,K,2).EQ.LOC) GO TO 1000
  501 CONTINUE
C         SINCE THERE IS NO INTERFACE IDENTIFY THE PRODUCT
  505 DO 510 K=1,NPS
      LL=K
      IF((IP(NP-1,K,2).LT.LOC).AND.(IP(NP-1,K,3).GT.LOC)) GO TO 520
  510 CONTINUE
C         LL NOW GIVES THE PRODUCT SEQUENCE NO
C         CHECK IF A NEW INTERFACE IS CREATETED
  520 IF(IP(NP-1,LL,1).EQ.IZ) GO TO 750
C         NEW INTERFACE IS CREATED
      GO TO 525
  750 CALL PSTAT0
      GO TO 3000
  525 CALL PSTAT1
      GO TO 3000
C         THE PRODUCT TO BE PUMPED MEETS AN INTERFACE
C         IT IS POSSIBLE THAT THE PRODUCT TO BE PUMPED IS SAME AS
C           A. PRODUCT TO THE LEFT OF INTERFACE
C           B. PRODUCT TO THE RIGHT OF INTERFACE
C           C. NEITHER OF THESE TWO PRODUCTS
C
 1000 IF(IP(NP-1,LL,1).EQ.IZ) GO TO 1010
      GO TO 1020
 1010 CALL PSTAT3
      GO TO 3000
 1020 IF(IP(NP-1,LL+1,1).EQ.IZ) GO TO 1031
      CALL PSTAT5
      GO TO 3000
```

```
 1031 CALL PSTAT4
      GO TO 3000
C
C
C         INTERFACE COUNTER
C
C
C         CHECK FOR TYPE 0 INTERFACE.
 3000 IF (INX(NP).EQ.0) GO TO 3010
      GO TO 3011
C         CHECK FOR TYPE 1 INTERFACE.
 3010 IFACE(NP)=IFACE(NP-1)
      GO TO 3050
 3011 IF(INX(NP).EQ.1) GO TO 3012
      GO TO 3013
 3012 IF(NREF(NP).EQ.1) GO TO 3026
      IF((NREF(NP).EQ.NREF(NP-1)).AND.(INX(NP-1).NE.0)) GO TO 3028
      IFACE(NP)=IFACE(NP-1)+400
      FCNT=FCNT+2.0
      GO TO 3050
C         CHECK FOR TYPE 3 OR 4 INTERFACE.
 3013 IF((INX(NP).EQ.3).OR.(INX(NP).EQ.4)) GO TO 3014
      GO TO 3015
 3014 IFACE(NP)=IFACE(NP-1)+100
      FCNT=FCNT+0.5
      GO TO 3050
C         CHECK FOR TYPE 5 INTERFACE.
 3015 IF(INX(NP).EQ.5) GO TO 3025
      GO TO 6000
 3025 IF(NREF(NP).EQ.1) GO TO 3026
      GO TO 3027
 3026 INX(NP)=6
      GO TO 3040
 3027 IF(NREF(NP).EQ.NREF(NP-1)) GO TO 3028
      GO TO 3035
 3028 INX(NP)=2
      GO TO 3040
C         CHECK IF ANY DOWNSTREAM PUMPING OCCURED AFTER THE
C         LAST PUMPING FROM THIS STATION. IF NO DOWNSTREAM
C         PUMPING OCCURED,EVEN UNDER TYPE 5 CONDITION THE NUMBER
C         OF INTERFACES CREATED IS ONLY ONE.
 3035 NQ=NP-1
      IF(NQ.EQ.1) GO TO 3039
 3038 IF(NREF(NQ).LT.NREF(NP)) GO TO 3039
      NQ=NQ-1
      IF(NQ.EQ.1) GO TO 3039
      IF(NREF(NQ).EQ.NREF(NP)) GO TO 3028
      GO TO 3038
```

```
 3039 IFACE(NP)=IFACE(NP-1)+400
      FCNT=FCNT+2.0
      GO TO 3050
 3040 IFACE(NP)=IFACE(NP-1)+200
      FCNT=FCNT+1.0
C        NOIF: NO. OF INTERFACES PRESENT IN THE PIPELINE.
C        IADD: ADDITIONAL INTERFACE VOLUME CREATED.
C        FTM: TIME AT THE END OF PUMPING.
 3050 NOIF=NPS-1
      IADD=IFACE(NP)-IFACE(NP-1)
      ITOTV=ITOTV+NBVOL
      FTM=TNOW+PTM
C
C        PRINT STATEMENTS. NOTE THAT THESE STATEMENTS ARE COMPLETELY
C        SKIPPED IF NPARM=1.
C
      IF(NPARM.EQ.1) GO TO 3700
      IF(LOC.NE.1) GO TO 3350
      WRITE(NPRNT,3360)
      GO TO 3500
 3350 IF(LOC.NE.1209) GO TO 3370
      WRITE (NPRNT,3380)
      GO TO 3500
 3370 IF(LOC.NE.4060) GO TO 3390
      WRITE(NPRNT,3400)
      GO TO 3500
 3390 IF(LOC.NE.15604) GO TO 3410
      WRITE(NPRNT,3420)
      GO TO 3500
 3410 IF(LOC.NE.19504) GO TO 3430
      WRITE (NPRNT,3440)
      GO TO 3500
 3430 IF(LOC.NE.24671) GO TO 3450
      WRITE (NPRNT,3460)
      GO TO 3500
 3450 IF(LOC.NE.13124) GO TO 3452
      WRITE (NPRNT,3454)
      GO TO 3500
 3452 IF(LOC.NE.24672) GO TO 3456
      WRITE(NPRNT,3458)
      GO TO 3500
 3456 WRITE(NPRNT,3470)
 3500 WRITE(NPRNT,3510) NBVOL
      WRITE(NPRNT,9200) BVOL
      WRITE (NPRNT,3511) IZ
      WRITE(NPRNT,3472) TNOW
      WRITE(NPRNT,3473) PTM
      WRITE(NPRNT,3512) AINV(II,JJ)
```

```
      WRITE(NPRNT,3513) AMAV(II,JJ)
      WRITE(NPRNT,3514) AMIV(II,JJ)
      IF(NO(NP).EQ.1) WRITE (NPRNT,3515)
C
C        PRINT OUT PIPE STATUS AFTER EVERY 5 PUMPINGS
C        IF JPARM=0
C
      IF(JPARM.EQ.1) GO TO 3519
      NR=MOD(NP,5)
      IF(NR.EQ.0) GO TO 3519
      GO TO 3596
 3519 WRITE(NPRNT,3520)
      NPP=NP-1
      DO 3530 J=1,NPS
      WRITE (NPRNT,3521) J
      DO 3540 K=1,6
      WRITE(NPRNT,3550) NPP,J,K,IP(NP,J,K)
 3540 CONTINUE
 3530 CONTINUE
 3535 WRITE(NPRNT,3570) INX(NP)
      WRITE (NPRNT,3575) NOIF
      WRITE (NPRNT,3580) IADD
      WRITE (NPRNT,3590) IFACE(NP)
      WRITE(NPRNT,3576) IFACE(1)
      WRITE(NPRNT,3597) ITCTV
      GO TO 3596
C
C        THE FOLLOWING PRINTING STATEMENTS ARE EXECUTED ONLY
C        IF NPARM=1.
C
 3700 NPP=NP-1
      WRITE(NPRNT,3705) NPP,NREF(NP),IZ,TNOW,ETM,NRVOL,INX(NP)
      IF(INX(NP).NE.0) WRITE(NPRNT,3710) IADD
C
C        INCREASE PUMPING NO BY ONE AND UPDATE THE PRESENT
C        TIME.
C
 3596 NP=NP+1
      TNOW=TNOW+PTM
C
C        IF TOTAL TIME IS MORE THAN ALTM BREAK THE SCHEDULE.
C
      IF(TNOW.GE.ALTM) GO TO 3598
      GO TO 90
 3598 NPP=NP-1
      NPQ=NP-2
      IF (NPARM.EQ.1) GO TO 4000
      IF (JPARM.EQ.1) GO TO 3599
```

```
      NR=MOD(NPP,5)
      IF(NR.NE.0) GO TO 4000
      GO TO 3599
C        PRINT THE PIPE STATUS.
 4000 WRITE (NPRNT,5520)
      WRITE(NPRNT,5555)
      DO 4100 J=1,NPS
      WRITE(NPRNT,5556) J,IP(NPP,J,1),IP(NPP,J,2),IP(NPP,J, ),
     1IP(NPP,J,6)
 4100 CONTINUE
 3599 IFNP=NP-2
      IXIF=IFACE(NP-1)-IFACE(1)
C        PRINT THE SUMMARY OF THE SCHEDULE.
      WRITE(NPRNT,3600)
      WRITE(NPRNT,3610) IFNP
      WRITE(NPRNT,3620) FCNT
      WRITE(NPRNT,3630) IXIF
      WRITE (NPRNT,3631) ITOTV
      WRITE(NPRNT,3635) ETM
      WRITE(NPRNT,3636) TTPS
C        RATIO: RATIO OF INTERFACE VOLUME TO TOTAL VOLUME.
      RATIO=(FLOAT(IXIF)/FLOAT(ITOTV))*100.0
      WRITE (NPRNT,3640) RATIO
C        RE INITIALIZE THE PIPE STATUS.
      DO 3675 I=1,NPS
      DO 3680 J=1,6
      IP(1,I,J)=IP(NP-1,I,J)
 3680 CONTINUE
 3675 CONTINUE
      IFACE(1)=NCIF*200
      NOSDL=NOSDL+1
      WRITE(NPRNT,3685) IFACE(1)
C        CHECK IF ALL THE SCHEDULES ARE GENERATED.
      IF(NOSDL.EQ.(NSHDL+1)) GO TO 6000
      GO TO 47
 6000 STOP
      END
```

```
      SUBROUTINE PSTATO
C
C        THIS SUBROUTINE UPDATES THE PIPE STATUS IF TYPE 2 INTERFACE
C        IS CREATED
C
      COMMON IP(200,25,6),INX(200)
      COMMON IZ,NBVOL,LOC,LL,NP,NPS,LIMIT
C
      INX(NP)=0
      IP(NP,LL,1)=IP(NP-1,LL,1)
      IP(NP,LL,2)=IP(NP-1,LL,2)
      IP(NP,LL,3)=IP(NP-1,LL,3)+NBVOL
      IP(NP,LL,4)=IP(NP-1,LL,4)
      IP(NP,LL,5)=IP(NP-1,LL,5)
      IP(NP,LL,6)=IP(NP-1,LL,6)+NBVOL
C        CHECK IF THE PRODUCT TO BE PUMPED WILL OCCUPY THE ENTIRE
C        VOLUME TO THE RIGHT
      IF(IP(NP,LL,3).GE.LIMIT) GO TO 760
      GO TO 770
  760 IP(NP,LL,3)=LIMIT
      IP(NP,LL,5)=0
      IP(NP,LL,6)=LIMIT-IP(NP,LL,2)
      NNPS=LL
C        GO TO STATEMENT 800 TO UPDATE THE STATUS OF ALL PRODUCTS
C        TO THE LEFT OF LOC
      GO TO 800
C        UPDATE THE STATUS OF ALL PRODUCTS TO THE RIGHT. CHECK SIMULTANIOUS
C        IF THE DELIVERY POINT HAS BEEN REACHED
C
  770 LL1=LL+1
      DO 771 J=LL1,NPS
      NNPS=J
      IP(NP,J,1)=IP(NP-1,J,1)
      IP(NP,J,2)=IP(NP,J-1,3)
      IP(NP,J,3)=IP(NP,J,2)+IP(NP-1,J,6)
      IP(NP,J,4)=IP(NP-1,J,4)
      IP(NP,J,5)=IP(NP-1,J,5)
      IP(NP,J,6)=IP(NP-1,J,6)
      IF(IP(NP,J,3).GE.LIMIT) GO TO 780
  790 GO TO 771
  780 IP(NP,J,3)=LIMIT
      IP(NP,J,5)=0
      IP(NP,J,6)=LIMIT-IP(NP,J,2)
      GO TO 800
  771 CONTINUE
  800 NPS=NNPS
      LLM=LL-1
      IF(LLM.EQ.0) GO TO 811
```

```
      DO 810 J=1,LLM
      DO 820 K=1,6
      IP(NP,J,K)=IP(NP-1,J,K)
  820 CONTINUE
  810 CONTINUE
  811 RETURN
      END
```

```
      SUBROUTINE PSTAT1
C
C        THIS SUBROUTINE UPDATES THE PIPE STATUS IF TYPE 1
C        INTERFACE IS CREATED.
C
      COMMON IP(200,25,6),INX(200)
      COMMON IZ,NBVOL,LOC,LL,NP,NPS,LIMIT
C
      INX(NP)=1
C        CHECK IF THE VOLUME TO BE PUMPED REPLACES THE ENTIRE VOLUME
C        TO THE RIGHT
      IF(NBVOL.GE.(LIMIT-LOC)) GO TO 530
      GO TO 540
  530 NPS=LL+1
      IP(NP,LL+1,1)=IZ
      IP(NP,LL+1,2)=LOC
      IP(NP,LL+1,3)=LIMIT
      IP(NP,LL+1,4)=IP(NP-1,LL,1)
      IP(NP,LL+1,5)=0
      IP(NP,LL+1,6)=LIMIT-LOC
      GO TO 535
C        NEW PRODUCT DOES NOT REPLACE ENTIRE VOLUME TO THE RIGHT
  540 IP(NP,LL+1,1)=IZ
      IP(NP,LL+1,2)=LOC
      IP(NP,LL+1,3)=LOC+NBVOL
      IP(NP,LL+1,4)=IP(NP-1,LL,1)
      IP(NP,LL+1,5)=IP(NP-1,LL,1)
      IP(NP,LL+1,6)=NBVOL
C        UPDATE STATUS OF SECOND PRODUCT TO THE RIGHT OF LOC
      IP(NP,LL+2,1)=IP(NP-1,LL,1)
      IP(NP,LL+2,2)=IP(NP,LL+1,3)
      IP(NP,LL+2,3)=IP(NP,LL+2,2)+(IP(NP-1,LL,3)-LOC)
      IP(NP,LL+2,4)=IP(NP,LL+1,1)
      IP(NP,LL+2,5)=IP(NP-1,LL,5)
      IP(NP,LL+2,6)=IP(NP,LL+2,3)-IP(NP,LL+2,2)
      IF(IP(NP,LL+2,3).GE.LIMIT) GO TO 551
      GO TO 561
  551 IP(NP,LL+2,3)=LIMIT
      IP(NP,LL+2,5)=0
      IP(NP,LL+2,6)=LIMIT-IP(NP,LL+2,2)
      NPS=LL+2
      GO TO 535
C        SECOND PRODUCT TO THE RIGHT OF LOCATION DID NOT OCCUPY
C        THE FULL VOLUME. UPDATE THE STATUS OF ALL PRODUCTS BEGINNING
C        FROM THE THIRD,CHECKING SIMULTANEOUSLY IF THE DELIVERY
C        POINT HAS BEEN REACHED.
C
  561 N36=LL+2
```

```
      NN7=NPS+3
      DO 570 J=NN6,NN7
      NNPS=J
      IP(NP,J+1,1)=IP(NP-1,J-1,1)
      IP(NP,J+1,2)=IP(NP,J,3)
      IP(NP,J+1,3)=IP(NP-1,J-1,6)+IP(NP,J+1,2)
      IP(NP,J+1,4)=IP(NP,J,1)
      IP(NP,J+1,5)=IP(NP-1,J-1,5)
      IP(NP,J+1,6)=IP(NP-1,J-1,6)
      IF(IP(NP,J+1,3).GE.LIMIT) GO TO 580
      GO TO 570
  580 IP(NP,J+1,3)=LIMIT
      IP(NP,J+1,5)=0
      IP(NP,J+1,6)=LIMIT-IP(NP,J+1,2)
      NPS=NNPS+1
      GO TO 535
  570 CONTINUE
C        UPDATE THE PRODUCTS BEHIND EXCEPT ONE IMMEDIATELY BEHIND
  535 NN5=LL-1
      IF(NN5.EQ.0) GO TO 555
      DO 550 J=1,NN5
      DO 560 K=1,6
      IP(NP,J,K)=IP(NP-1,J,K)
  560 CONTINUE
  550 CONTINUE
C        UPDATE STATUS OF THE PRODUCT THAT IS IMMEDIATELY BEHIND
  555 IP(NP,LL,1)=IP(NP-1,LL,1)
      IP(NP,LL,2)=IP(NP-1,LL,2)
      IP(NP,LL,3)=LOC
      IP(NP,LL,4)=IP(NP-1,LL,4)
      IP(NP,LL,5)=I7
      IP(NP,LL,6)=LOC-IP(NP,LL,2)
      RETURN
      END
```

```
      SUBROUTINE PSTAT3
C
C        THIS SUBROUTINE UPDATES THE PIPE STATUS IF
C        TYPE 3 INTERFACE IS CREATED.
C
      COMMON IP(200,25,6),INX(200)
      COMMON IZ,NBVEL,LOC,LL,NP,NPS,LIMIT
C
      INX(NP)=3
      IP(NP,LL,1)=IP(NP-1,LL,1)
      IP(NP,LL,2)=IP(NP-1,LL,2)
      IP(NP,LL,3)=IP(NP-1,LL,3)+NBVEL
      IP(NP,LL,4)=IP(NP-1,LL,4)
      IP(NP,LL,5)=IP(NP-1,LL,5)
      IP(NP,LL,6)=IP(NP,LL,3)-IP(NP,LL,2)
C        CHECK IF THE PRODUCT TO BE PUMPED OCCUPYS THE ENTIRE VOLUME
C        TO THE RIGHT
      IF(IP(NP,LL,3).GE.LIMIT) GO TO 1028
      GO TO 1030
 1028 IP(NP,LL,3)=LIMIT
      IP(NP,LL,5)=0
      IP(NP,LL,6)=LIMIT-LOC
      NPS=LL
      GO TO 2000
C        THE PRODUCT PUMPED DOES NOT OCCUPY THE ENTIRE VOLUME TO
C        THE RIGHT. UPDATE THE STATUS OF ALL PRODUCTS TO THE RIGHT
C        CHECKING SIMULTANEOUSLY IF THE DELIVERY POINT HAS BEEN REACHED
 1030 NLN=LL+1
      DO 1040 J=NLN,NPS
      NNPS=J
      IP(NP,J,1)=IP(NP-1,J,1)
      IP(NP,J,2)=IP(NP,J-1,3)
      IP(NP,J,3)=IP(NP,J,2)+IP(NP-1,J,6)
      IP(NP,J,4)=IP(NP-1,J,4)
      IP(NP,J,5)=IP(NP-1,J,5)
      IP(NP,J,6)=IP(NP-1,J,6)
      IF(IP(NP,J,3).GE.LIMIT) GO TO 1050
 1040 CONTINUE
 1050 IP(NP,NNPS,3)=LIMIT
      IP(NP,NNPS,5)=0
      IP(NP,NNPS,6)=LIMIT-IP(NP,NNPS,2)
      NPS=NNPS
      GO TO 2000
C        UPDATE THE STATUS OF ALL PRODUCTS TO THE LEFT
 2000 LLNJ=LL-1
      IF(LLNJ.EQ.0) GO TO 2011
      DO 2010 J=1,LLNJ
      DO 2020 K=1,6
```

```
      IP(NP,J,K)=IP(NP-1,J,K)
 2020 CONTINUE
 2010 CONTINUE
 2001 RETURN
      END
```

```
      SUBROUTINE PSTAT4
C
C        THIS SUBROUTINE UPDATES THE PIPE STATUS IF
C        TYPE 4 INTERFACE IS CREATED.
C
      COMMON IP(200,25,6),INX(200)
      COMMON IZ,NBVOL,LOC,LL,NP,NPS,LIMIT
C
      INX(NP)=4
      IP(NP,LL+1,1)=IP(NP-1,LL+1,1)
      IP(NP,LL+1,2)=LOC
      IP(NP,LL+1,3)=IP(NP-1,LL+1,3)+NBVOL
      IP(NP,LL+1,4)=IP(NP-1,LL+1,4)
      IP(NP,LL+1,5)=IP(NP-1,LL+1,5)
      IP(NP,LL+1,6)=IP(NP,LL+1,3)-IP(NP,LL+1,2)
C        CHECK IF THE NEW PRODUCT OCCUPYS THE ENTIRE VOLUME TO THE RIGHT
      IF(IP(NP,LL+1,3).GE.LIMIT) GO TO 1051
      GO TO 1060
 1051 IP(NP,LL+1,3)=LIMIT
      IP(NP,LL+1,5)=0
      IP(NP,LL+1,6)=LIMIT-IP(NP,LL+1,2)
      NPS=LL+1
C        UPDATE THE STATUS OF ALL PRODUCTS TO THE LEFT
      GO TO 2500
C        THE FIRST PRODUCT DID NOT OCCPY THE ENTIRE VOLUME TO THE
C        RIGHT. UPDATE THE STATUS OF ALL PRODUCTS TO THE RIGHT
C        CHECKING AT THE SAME TIME IF DELIVERY POINT HAS BEEN
C        REACHED
 1060 LL2=LL+2
      NPQ=NPS
      DO 1070 J=LL2,NPQ
      MNPS=J
      IP(NP,J,1)=IP(NP-1,J,1)
      IP(NP,J,2)=IP(NP,J-1,3)
      IP(NP,J,3)=IP(NP,J,2)+IP(NP-1,J,6)
      IP(NP,J,4)=IP(NP-1,J,4)
      IP(NP,J,5)=IP(NP-1,J,5)
      IP(NP,J,6)=IP(NP,J,3)-IP(NP,J,2)
      IF(IP(NP,J,3).GE.LIMIT) GO TO 1080
      GO TO 1070
 1080 IP(NP,J,3)=LIMIT
      IP(NP,J,5)=0
      IP(NP,J,6)=LIMIT-IP(NP,J,2)
      NPS=MNPS
      GO TO 2500
 1070 CONTINUE
C        UPDATE THE STATUS OF ALL PRODUCTS TO THE LEFT
C
```

```
 2500 DO 2600 J=1,L1
      DO 2700 K=1,6
      IP(NP,J,K)=IP(NP-1,J,K)
 2700 CONTINUE
 2600 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PSTAT5
C
C        THIS SUBROUTINE UPDATES THE PIPE STATUS
C        IF TYPE 5 INTERFACE IS CREATED.
C
      COMMON IP(200,25,6),INX(200)
      COMMON IZ,NBVOL,LOC,LL,NP,NPS,LIMIT
C
C        THE PRODUCT TO BE PUMPED IS NOT THE PRODUCT ON EITHER
C        SIDE OF INTERFACE
      INX(NP)=5
      IP(NP,LL+1,1)=IZ
      IP(NP,LL+1,2)=LOC
      IP(NP,LL+1,3)=LOC+NBVOL
      IP(NP,LL+1,4)=IP(NP-1,LL,1)
      IP(NP,LL+1,5)=IP(NP-1,LL,5)
      IP(NP,LL+1,6)=NBVOL
C        CHECK IF THE NEW PRODUCT OCCUPYS THE ENTIRE VOLUME TO THE RIGHT
      IF(IP(NP,LL+1,3).GE.LIMIT) GO TO 1053
      GO TO 1054
 1053 IP(NP,LL+1,3)=LIMIT
      IP(NP,LL+1,5)=0
      IP(NP,LL+1,6)=LIMIT-IP(NP,LL+1,2)
      NPS=LL+1
C        UPDATE THE STATUS OF ALL PRODUCTS TO THE LEFT
      GO TO 2800
C        UPDATE THE STATUS OF THE SECOND PRODUCT
 1054 IP(NP,LL+2,1)=IP(NP-1,LL+1,1)
      IP(NP,LL+2,2)=IP(NP,LL+1,3)
      IP(NP,LL+2,3)=IP(NP,LL+2,2)+IP(NP-1,LL+1,6)
      IP(NP,LL+2,4)=IZ
      IP(NP,LL+2,5)=IP(NP-1,LL+1,5)
      IP(NP,LL+2,6)=IP(NP-1,LL+1,6)
      IF(IP(NP,LL+2,3).GE.LIMIT) GO TO 1055
      GO TO 1063
 1055 IP(NP,LL+2,3)=LIMIT
      IP(NP,LL+2,6)=LIMIT-IP(NP,LL+2,2)
      NPS=LL+2
      GO TO 2800
C        THE NEW PRODUCT DID NOT OCCUPY THE ENTIRE VOLUME TO THE
C        RIGHT. UPDATE THE STATUS OF ALL PRODUCTS TO THE RIGHT
C        CHECKING AT THE SAME TIME IF THE DELIVERY POINT HAS BEEN
C        REACHED
 1063 LLM2=LL+3
      NNQ=NPS+1
      DO 1075 J=LLM2,NNQ
      NNPS=J
      IP(NP,J,1)=IP(NP-1,J-1,1)
```

```
      IP(NP,J,2)=IP(NP,J-1,3)
      IP(NP,J,3)=IP(NP,J,2)+IP(NP-1,J-1,6)
      IP(NP,J,4)=IP(NP,J-1,1)
      IP(NP,J,5)=IP(NP-1,J-1,5)
      IP(NP,J,6)=IP(NP-1,J-1,6)
      IF(IP(NP,J,3).GE.LIMIT) GO TO 1085
      GO TO 1075
 1085 IP(NP,J,3)=LIMIT
      IP(NP,J,5)=0
      IP(NP,J,6)=LIMIT-IP(NP,J,2)
      NPS=NNPS
      GO TO 2800
 1075 CONTINUE
 2800 NBR=LL-1
      IF(NBR.EQ.0) GO TO 2950
      DO 2850 J=1,NBR
      DO 2900 K=1,6
      IP(NP,J,K)=IP(NP-1,J,K)
 2900 CONTINUE
 2850 CONTINUE
 2950 IP(NP,LL,1)=IP(NP-1,LL,1)
      IP(NP,LL,2)=IP(NP-1,LL,2)
      IP(NP,LL,3)=LOC
      IP(NP,LL,4)=IP(NP-1,LL,4)
      IP(NP,LL,5)=17
      IP(NP,LL,6)=IP(NP,LL,3)-IP(NP,LL,2)
      RETURN
      END
```

BEGINNING OF SCHEDULE NO: 1

TANK STATUS AT THE BEGINNING OF SCHEDULE:

STATION	TANK NO.	MAXI VOL BBLS	MIN VOL BBLS	INTL VOL BBLS	PROD RATE BBLS/DAY	OVFLO TIME HRS
1	1	6800.00	450.00	4429.00	1950.00	29.18
1	2	3600.00	360.00	360.00	0.0	99999.00
2	1	7300.00	750.00	2000.00	1800.00	70.67
2	2	4500.00	750.00	2600.00	900.00	50.67
2	3	1800.00	750.00	950.00	340.00	60.00
3	1	3300.00	350.00	1040.00	510.00	106.35
3	2	1600.00	250.00	1380.00	170.00	31.06
4	1	32000.00	3400.00	3400.00	0.0	99999.00
4	2	17000.00	1700.00	1700.00	0.0	99999.00
5	1	5000.00	600.00	1654.00	715.00	112.31
5	2	3000.00	400.00	1409.00	405.00	94.28
5	3	2300.00	300.00	1151.00	300.00	91.92
6	1	3600.00	360.00	1700.00	730.00	62.47
7	1	2050.00	250.00	250.00	0.0	99999.00
7	2	1550.00	150.00	740.00	335.00	58.03
7	3	1700.00	150.00	635.00	212.00	120.57
8	1	4200.00	300.00	300.00	0.0	99999.00
8	2	6000.00	200.00	200.00	0.0	99999.00
8	3	4500.00	100.00	100.00	0.0	99999.00
9	1	5000.00	500.00	500.00	0.0	99999.00

MINIMUM ALLOWABLE PUMPING TIME: 30.00 MINUTES.
THE PRODUCTION PERIOD IS: 96.00 HOURS

THE DETAILS OF THE SCHEDULE ARE:

PUMPING NO	STATION NO	PRODUCT NO	STARTING TIME HOURS	FINISHING TIME HOURS	VOLUME PUMPED BBLS	TYPE OF INFACE	INFACE VOL BBLS	WAITING TIME HOURS
1	1	1	0.0	9.97	4785	0		
2	2	1	9.97	13.59	2264	0		
3	5	1	13.59	16.14	1529	0		
4	3	1	16.14	17.77	1062	0		
5	1	1	17.77	19.36	765	0		
6	2	1	19.36	20.13	492	0		
								10.07
7	1	1	30.22	31.06	401	0		
8	3	6	31.06	33.15	1339	1	400	
9	2	1	33.15	34.92	1107	0		
10	1	1	34.92	37.09	1036	0		
11	5	1	37.09	38.18	656	0		
12	3	1	38.18	38.87	448	0		
13	2	1	38.87	39.41	336	0		
								2.95
14	1	1	42.36	43.44	516	0		
15	2	1	43.44	43.99	343	0		
								6.68
16	2	3	50.67	57.04	3984	1	400	
17	2	2	57.04	58.03	617	2	200	
18	7	6	58.03	60.63	1431	1	400	
19	7	5	60.63	62.47	1008	2	200	
20	6	4	62.47	67.69	3393	1	400	
21	1	1	67.69	72.63	2371	0		
22	5	6	72.63	76.45	2294	0		
23	2	1	76.45	80.88	2766	0		
24	5	1	80.88	83.11	1328	0		
25	3	1	83.11	84.60	971	0		
26	1	1	84.60	87.05	1171	0		
27	2	1	87.05	87.89	525	0		
28	7	6	87.89	88.60	390	0		
								3.32
29	5	5	91.92	95.32	2037	1	400	
30	5	6	95.32	95.86	327	2	200	

THE PIPE STATUS AT THE END OF LAST PUMPING:

PRODUCT SEQUENCE NO.	PRODUCT CODE NO.	BEGINING POINT BBLS	ENDING POINT BBLS	VOLUME BBLS
1	1	0	9013	9013
2	2	9013	9630	617
3	3	9630	13614	3984

4	1	13614	15604	1990
5	6	15604	15931	327
6	5	15931	17968	2037
7	1	17968	23955	5987
8	6	23955	27999	4043
9	1	27999	31786	3786

END OF SCHEDULE: SUMMARY.

NUMBER OF PUMPINGS IN THIS PERIOD IS: 30
TOTAL NUMBER OF INTERFACES CREATED IN THIS PERIOD IS: 13.00
TOTAL INTERFACE VOLUME CREATED IN THIS PERIOD IS: 2600 BBLS
TOTAL VOLUME PUMPED IN THIS PERIOD: 41720 BBLS
THE SCHEDULE PERIOD IS: 95.86 HOURS
TOTAL IDLE PERIOD OF PIPELINE DURING SCHEDULE: 23.03 HOURS
RATIO OF INTERFACE VOL TO TOTAL VOL: 6.23 %

INTERFACE VOLUME AT THE START OF NEXT SCHEDULE: 1600 BBLS

BEGINNING OF SCHEDULE NO: 2

TANK STATUS AT THE BEGINNING OF SCHEDULE:

STATION	TANK NO.	MAXI VOL BBLS	MIN VOL BBLS	INIT VOL BBLS	PMP RATE BBLS/DAY	OVFLO TIME HRS
1	1	6800.00	450.00	1182.59	2310.00	59.36
1	2	3600.00	360.00	360.00	0.0	99999.00
2	1	7300.00	750.00	1363.55	2650.00	65.75
2	2	4500.00	750.00	2215.96	0.0	99999.00
2	3	1800.00	750.00	1692.04	0.0	99999.00
3	1	3300.00	350.00	597.15	540.00	120.13
3	2	1600.00	250.00	700.18	0.0	99999.00
4	1	32000.00	3450.00	7400.00	0.0	99999.00
4	2	17000.00	1700.00	1700.00	0.0	99999.00
5	1	5000.00	600.00	989.03	0.0	99999.00
5	2	3000.00	400.00	407.33	0.0	99999.00
5	3	2300.00	300.00	313.55	0.0	99999.00
6	1	3600.00	360.00	1226.19	820.00	69.48
7	1	2050.00	250.00	250.00	430.00	100.47
7	2	1550.00	150.00	258.35	280.00	110.71
7	3	1700.00	150.00	474.37	210.00	140.93
8	1	4200.00	300.00	300.00	0.0	99999.00
8	2	6000.00	200.00	200.00	156.00	892.31
8	3	4500.00	100.00	100.00	0.0	99999.00
9	1	5000.00	500.00	500.00	0.0	99999.00

MINIMUM ALLOWABLE PUMPING TIME: 30.00 MINUTES.
THE PRODUCTION PERIOD IS: 48.00 HOURS

THE DETAILS OF THE SCHEDULE ARE:

PUMPING NO	STATION NO	PRODUCT NO	STARTING TIME HOURS	FINISHING TIME HOURS	VOLUME PUMPED BBLS	TYPE OF INFACE	INFACE VOL BBLS	WAITING TIME HOURS
1	1	1	0.0	1.90	910	0		
2	2	1	1.90	3.22	830	0		
3	5	1	3.22	3.86	384	0		
4	3	1	3.86	4.39	340	0		
5	1	1	4.39	5.01	300	0		
								4.55
6	1	1	9.56	10.70	547	0		
7	2	1	10.70	11.62	577	0		
								15.35
8	1	1	26.97	31.05	1959	0		
9	4	1	31.05	37.20	3994	0		
10	2	1	37.20	40.36	1975	0		
11	1	1	40.36	42.70	1120	0		
12	3	1	42.70	44.07	892	0		

THE PIPE STATUS AT THE END OF LAST PUMPING:

PRODUCT SEQUENCE NO.	PRODUCT CODE NO.	BEGINING POINT BBLS	ENDING POINT BBLS	VOLUME BBLS
1	1	0	22457	22457
2	2	22457	23074	617
3	3	23074	27058	3984
4	1	27058	29432	2374
5	6	29432	29759	327
6	5	29759	31786	2027

END OF SCHEDULE: SUMMARY.

NUMBER OF PUMPINGS IN THIS PERIOD IS: 12
TOTAL NUMBER OF INTERFACES CREATED IN THIS PERIOD IS: 0.0
TOTAL INTERFACE VOLUME CREATED IN THIS PERIOD IS: 0 BBLS
TOTAL VOLUME PUMPED IN THIS PERIOD: 13828 BBLS
THE SCHEDULE PERIOD IS: 44.07 HOURS
TOTAL IDLE PERIOD OF PIPELINE DURING SCHEDULE: 19.89 HOURS
RATIO OF INTERFACE VOL TO TOTAL VOL: 0.0 %

INTERFACE VOLUME AT THE START OF NEXT SCHEDULE: 1000 BBLS

BEGINNING OF SCHEDULE NO: 3

TANK STATUS AT THE BEGINNING OF SCHEDULE:

STATION	TANK NO.	MAXI VOL BBLS	MIN VOL BBLS	INTL VOL BBLS	PROD RATE BBLS/DAY	OVFLO TIME HRS
1	1	6800.00	450.00	969.56	0.0	99999.00
1	2	3600.00	360.00	360.00	0.0	99999.00
2	1	7300.00	750.00	1250.15	1821.00	79.34
2	2	4500.00	750.00	2215.96	1105.00	49.61
2	3	1800.00	750.00	1692.04	321.00	[illegible].67
3	1	3300.00	350.00	443.45	557.00	12[illegible].06
3	2	1600.00	250.00	700.18	205.00	105.34
4	1	32000.00	3400.00	3405.00	0.0	99999.00
4	2	17000.00	1700.00	1700.00	0.0	99999.00
5	1	5000.00	600.00	605.00	685.00	155.99
5	2	3000.00	400.00	407.33	405.00	153.64
5	3	2300.00	300.00	313.55	302.00	157.66
6	1	3600.00	360.00	2866.19	783.00	22.49
7	1	2050.00	250.00	1110.00	0.0	99999.00
7	2	1550.00	150.00	818.55	288.00	60.97
7	3	1700.00	150.00	894.56	0.0	99999.00
8	1	4200.00	300.00	300.00	0.0	99999.00
8	2	6000.00	200.00	512.00	0.0	99999.00
8	3	4500.00	100.00	100.00	0.0	99999.00
9	1	5000.00	500.00	500.00	0.0	99999.00

MINIMUM ALLOWABLE PUMPING TIME: 30.00 MINUTES.
THE PRODUCTION PERIOD IS: 120.00 HOURS

THE DETAILS OF THE SCHEDULE ARE:

PUMPING NO	STATION NO	PRODUCT NO	STARTING TIME HOURS	FINISHING TIME HOURS	VOLUME PUMPED BBLS	TYPE OF INTERFACE	INTERFACE VOL BBLS	WAITING TIME HOURS
1	2	1	0.0	0.96	597	0		
2	1	1	0.96	2.02	510	0		
								6.05
3	2	2	8.07	9.78	1067	1	400	
4	2	3	9.78	13.08	2063	2	200	
5	6	4	13.08	17.62	3082	1	400	
6	7	1	17.62	19.38	854	0		
7	5	1	19.38	20.35	560	0		
								40.62
8	7	6	60.97	63.56	1426	1	400	
9	5	1	63.56	65.72	1245	0		
10	8	6	65.72	66.35	306	0		
								10.51
11	5	1	76.86	77.42	333	0		
								9.80
12	2	1	87.22	87.91	434	3	100	
13	2	2	87.91	89.62	1067	2	200	
14	2	3	89.62	92.94	2075	2	200	
15	2	1	92.94	104.86	7449	3	100	
								0.49
16	3	6	105.34	107.44	1362	1	400	
17	6	4	107.44	112.18	3078	1	400	
18	7	1	112.18	113.19	632	0		
19	3	1	113.19	117.52	2815	0		
20	2	1	117.52	118.12	374	0		

THE PIPE STATUS AT THE END OF LAST PUMPING:

PRODUCT SEQUENCE NO.	PRODUCT CODE NO.	BEGINING POINT BBLS	ENDING POINT BBLS	VOLUME BBLS
1	1	0	7881	7881
2	6	7881	9243	1362
3	1	9243	13841	4598
4	3	13841	15916	2075
5	2	15916	16983	1067
6	1	16983	17417	434
7	3	17417	19480	2063
8	2	19480	20547	1067
9	1	20547	23325	2778
10	4	23325	26403	3078
11	1	26403	31786	5383

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END OF SCHEDULE: SUMMARY.

NUMBER OF PUMPINGS IN THIS PERIOD IS: 20
TOTAL NUMBER OF INTERFACES CREATED IN THIS PERIOD  IS: 14.00
TOTAL INTERFACE VOLUME CREATED IN THIS PERIOD IS:     2800 BBLS
TOTAL VOLUME PUMPED IN THIS PERIOD:    31399 BBLS
THE SCHEDULE PERIOD IS: 118.17  HOURS
TOTAL IDLE PERIOD OF PIPELINE DURING SCHEDULE: 67.47 HOURS
RATIO OF INTERFACE VOL TO TOTAL VOL:  8.92 %

INTERFACE VOLUME AT THE START OF NEXT SCHEDULE:  2000 BBLS
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BEGINNING OF SCHEDULE NO: 4

TANK STATUS AT THE BEGINNING OF SCHEDULE:

STATION	TANK NO.	MAXI VOL BBLS	MIN VOL BBLS	INIL VOL BBLS	PROD RATE BBLS/DAY	OVFLW TIME HRS
1	1	6800.00	450.00	455.00	1900.00	60.15
1	2	3600.00	360.00	360.00	0.0	99999.00
2	1	7000.00	750.00	697.65	1780.00	86.32
2	2	4500.00	750.00	3602.68	910.00	2[illegible].67
2	3	1600.00	750.00	1161.33	310.00	49.45
3	1	3300.00	350.00	412.54	510.00	155.68
3	2	1600.00	250.00	362.27	375.00	79.11
4	1	32000.00	3400.00	7400.00	0.0	99999.00
4	2	17000.00	1700.00	5200.00	0.0	99999.00
5	1	5000.00	600.00	1620.42	685.00	111.40
5	2	3000.00	400.00	2432.33	400.00	34.06
5	3	2300.00	300.00	1623.55	300.00	56.12
6	1	3600.00	360.00	620.21	775.00	92.28
7	1	2050.00	250.00	255.00	0.0	99999.00
7	2	1550.00	150.00	632.24	310.00	55.57
7	3	1700.00	150.00	694.56	215.00	89.91
8	1	4200.00	300.00	300.00	310.00	301.94
8	2	6000.00	200.00	205.00	200.00	695.40
8	3	4500.00	100.00	100.00	0.0	99999.00
9	1	5000.00	500.00	500.00	0.0	99999.00

MINIMUM ALLOWABLE PUMPING TIME: 30.00 MINUTES.
THE PRODUCTION PERIOD IS: 168.00 HOURS

THE DETAILS OF THE SCHEDULE ARE:

PUMPING NO	STATION NO	PRODUCT NO	STARTING TIME HOURS	FINISHING TIME HOURS	VOLUME PUMPED BBLS	TYPE OF INTERFACE	INTERFACE VOL BBLS	WAITING TIME HOURS
1	4	1	0.0	6.15	3994	0		
2	5	1	6.15	8.58	1460	0		
3	2	1	8.58	9.99	883	0		
4	1	1	9.99	11.97	947	0		
								11.70
5	2	3	23.67	30.04	3986	1	400	
6	2	2	30.04	31.34	811	2	200	
7	5	6	31.34	34.06	1630	0		
8	1	1	34.06	38.12	1946	0		
9	5	5	38.12	41.51	2037	1	400	
10	5	6	41.51	43.38	1119	2	200	
11	2	1	43.38	47.87	2809	0		
12	7	6	47.87	50.28	1326	0		
13	5	1	50.28	52.37	1249	0		
14	1	1	52.37	55.49	1498	0		
15	3	1	55.49	57.46	1278	0		
16	4	3	57.46	59.76	1494	0		
17	2	1	59.76	61.36	1000	0		
18	1	1	61.36	62.52	556	0		
								15.29
19	2	1	77.81	79.21	877	0		
20	3	6	79.21	81.33	1378	1	400	
21	6	4	81.33	86.00	3052	1	400	
22	1	1	86.00	89.91	1876	0		
23	7	5	89.91	92.76	1570	1	400	
24	7	6	92.76	93.79	561	2	200	
25	2	1	93.79	96.56	1732	0		
26	5	1	96.56	98.77	1324	0		
27	1	1	98.77	101.24	1187	0		
28	3	1	101.24	102.72	961	0		
29	2	1	102.72	103.55	518	0		
30	8	1	103.55	106.35	1368	0		
31	1	1	106.35	107.36	483	0		
32	2	1	107.36	107.87	319	0		
								4.38
33	2	2	112.25	113.95	1067	1	400	
34	2	3	113.95	119.37	3387	2	200	
35	1	1	119.37	121.75	1139	0		
36	2	1	121.75	123.61	1167	0		
37	5	1	123.61	124.85	744	0		
38	1	1	124.85	125.47	294	0		
39	8	1	125.47	125.99	253	0		
								4.21
40	2	1	130.20	131.09	554	0		

41	3	1	131.09	132.05	623	0		
42	1	1	132.05	133.34	623	0		
								10.51
43	2	1	143.86	145.57	1074	0		
44	1	1	145.57	147.99	1159	0		
45	5	1	147.99	149.15	693	0		
46	7	6	149.15	150.48	732	0		
47	3	1	150.48	151.10	404	0		
48	1	1	151.10	151.84	464	0		
49	1	1	151.84	152.61	365	0		
50	8	6	152.61	155.25	1293	0		
								4.21
51	2	1	159.46	160.48	640	0		
52	1	1	160.48	162.04	746	0		
53	5	1	162.04	162.60	386	0		
								4.73
54	3	6	167.41	168.00	380	1	400	

THE PIPE STATUS AT THE END OF LAST PUMPING:

PRODUCT SEQUENCE NO.	PRODUCT CODE NO.	BEGINING POINT BBLS	ENDING POINT BBLS	VOLUME BBLS
1	1	0	4060	4060
2	6	4060	4440	380
3	1	4440	10841	6401
4	3	10841	14228	3387
5	2	14228	15295	1067
6	1	15295	27047	11752
7	6	27047	30450	3403
8	1	30450	31786	1336

END OF SCHEDULE: SUMMARY.

NUMBER OF PUMPINGS IN THIS PERIOD IS: 54
TOTAL NUMBER OF INTERFACES CREATED IN THIS PERIOD IS: 18.00
TOTAL INTERFACE VOLUME CREATED IN THIS PERIOD IS: 3600 BBLS
TOTAL VOLUME PUMPED IN THIS PERIOD: 65398 BBLS
THE SCHEDULE PERIOD IS: 168.00 HOURS
TOTAL IDLE PERIOD OF PIPELINE DURING SCHEDULE: 55.04 HOURS
RATIO OF INTERFACE VOL TO TOTAL VOL: 5.50 %

INTERFACE VOLUME AT THE START OF NEXT SCHEDULE: 1400 BBLS

BEGINNING OF SCHEDULE NO: 5

TANK STATUS AT THE BEGINNING OF SCHEDULE:

STATION	TANK NO.	MAXI VOL BBLS	MIN VOL BBLS	INTL VOL BBLS	PROD RATE BBLS/DAY	OVFLO TIME HRS
1	1	6800.00	450.00	926.82	1900.00	74.19
1	2	3600.00	360.00	360.00	0.0	99999.00
2	1	7300.00	750.00	1312.43	1760.00	81.65
2	2	4500.00	750.00	2399.81	910.00	50.14
2	3	1800.00	750.00	1452.11	310.00	26.86
3	1	3300.00	350.00	714.12	510.00	121.69
3	2	1600.00	250.00	1229.65	0.0	99999.00
4	1	32000.00	3400.00	10400.00	0.0	99999.00
4	2	17000.00	1700.00	1705.00	0.0	99999.00
5	1	5000.00	600.00	756.72	0.0	99999.00
5	2	3000.00	400.00	2482.04	0.0	99999.00
5	3	2300.00	300.00	1846.10	0.0	99999.00
6	1	3600.00	360.00	3012.92	775.00	18.18
7	1	2050.00	250.00	255.00	0.0	99999.00
7	2	1550.00	150.00	381.34	300.00	95.49
7	3	1700.00	150.00	628.98	215.00	97.23
8	1	4200.00	300.00	847.67	0.0	99999.00
8	2	6000.00	200.00	311.29	0.0	99999.00
8	3	4500.00	100.00	100.00	0.0	99999.00
9	1	5000.00	500.00	5500.00	0.0	99999.00

MINIMUM ALLOWABLE PUMPING TIME: 30.00 MINUTES.
THE PRODUCTION PERIOD IS: 72.00 HOURS

THE DETAILS OF THE SCHEDULE ARE:

PUMPING NO	STATION NO	PRODUCT NO	STARTING TIME HOURS	FINISHING TIME HOURS	VOLUME PUMPED BBLS	TYPE OF INFACE	INFACE VOL BBLS	WAITING TIME HOURS
1	2	1	0.0	1.01	631	0		
2	1	1	1.01	2.39	660	0		
3	8	1	2.39	3.49	542	0		
4	3	1	3.49	4.18	448	0		
								4.26
5	6	4	8.45	13.17	3073	1	400	
6	2	1	13.17	14.79	1010	0		
7	4	1	14.79	25.55	6594	0		
8	1	1	25.55	26.86	626	0		
9	2	2	26.86	28.56	1067	1	400	
10	2	3	28.56	33.55	3115	2	200	
11	1	1	33.55	38.14	2204	0		
12	2	1	38.14	41.25	1940	0		
13	3	1	41.25	42.50	814	0		
14	1	1	42.50	43.36	413	0		
								4.26
15	2	1	47.62	48.47	529	0		
16	1	1	48.47	49.48	484	0		
								15.29
17	1	1	64.77	67.79	1449	0		
18	2	1	67.79	70.36	1605	0		
19	3	1	70.36	71.30	612	0		
20	1	1	71.30	71.99	332	0		

THE PIPE STATUS AT THE END OF LAST PUMPING:

PRODUCT SEQUENCE NO.	PRODUCT CODE NO.	BEGINING POINT BBLS	ENDING POINT BBLS	VOLUME BBLS
1	1	0	11591	11591
2	3	11591	14706	3115
3	2	14706	15773	1067
4	1	15773	21999	6226
5	6	21999	22379	380
6	1	22379	31786	9407

END OF SCHEDULE: SUMMARY.

NUMBER OF PUMPINGS IN THIS PERIOD IS: 20
TOTAL NUMBER OF INTERFACES CREATED IN THIS PERIOD IS: 3.00
TOTAL INTERFACE VOLUME CREATED IN THIS PERIOD IS: 1000 BBLS
TOTAL VOLUME PUMPED IN THIS PERIOD: 28548 BBLS

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THE SCHEDULE PERIOD IS:  71.59  HOURS
TOTAL IDLE PERIOD OF PIPELINE DURING SCHEDULE: 23.82 HOURS
RATIO OF INTERFACE VOL TO TOTAL VOL:  3.50 %

INTERFACE VOLUME AT THE START OF NEXT SCHEDULE:  1000 BBLS
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AN ALGORITHMIC APPROACH TO SCHEDULING A MULTI-PRODUCT PIPELINE SYSTEM

by

ANANTH NARASIMHA PAI

B.E. (Mech.), University of Madras, India, 1967

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

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1972

This research is concerned with scheduling of petroleum products through a single, multi-product pipeline system. These petroleum products are produced in gas plants and stored in tanks situated at pump stations. Each storage tank has safe maximum and minimum levels and in order to keep the system feasible (maintaining the product levels in between the two safe levels), the products stored in them have to be pumped regularly, by means of a sequence of pumpings, known as the 'schedules'.

When different products are pumped through a single pipeline, different types of interfaces are created. Each interface represents a certain volume of degraded product which fetches less price than pure products. The schedules, therefore, should not only keep the system feasible but also minimize the number of interfaces.

An algorithm, based on certain scheduling rules, was developed for generating schedules. Its usefulness was then demonstrated by generating a sample schedule and finally it was tested by means of a simulation program.

It was found that the proposed scheduling procedure created only 0.053 bbl of interface per barrel of products pumped, whereas the existing procedure of scheduling created 0.083 bbl of interface per barrel of products pumped. The reduction in interface, obtained from proposed method, is therefore, 36.1%.