DEVELOPMENT OF MARGINAL OIL FIELDS IN WESTERN DESERT

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1. SUMMARY

Agiba is a joint venture company established between EGPC and IEOC and works in the exploration and production fields in Egypt on behalf of EGPC and IEOC, first shipment of production from Meleiha field to El-Hamra terminal was delivered in November 1986. By this date Agiba expanded its exploration activity and many areas were discovered such as: Ashrafi in Zeit Bay gulf of Suez, each of Ras El-Hekma, Aghar, Zarif, El-Raml and El-Faras fields located in Western Desert. Present average production is ± 49 Mbopd and ± 30 MMSCFD of gas. This paper shows Agiba experience in development of the marginal remote oil fields in the Egyptian western desert from the view of oil transportation to the nearest oil gathering plant located at Bapetco. In addition to the optimization for the development process, Zarif and El-Faras & El-Raml fields are taken as case histories

2. INTRODUCTION

In Zarif field, crude oil is separated in a gas oil separation plant and pumped to Meleiha main process area via 56 kilometers pipeline. As a way of cost optimization and making use of all available capabilities, the pipeline was made using tubing joints tested up to 2500 psi. In winter, faced the problem of increasing pumping pressure approaching testing pressure due to the difficulty of pumping high pour point crude, specially during night. Later on, part of the pipeline was looped as a mean of reducing pumping pressure, which improved pumping operation. Faras and Raml fields, both are in a remote area, their development plan passed through the following steps:

- Putting these wells on production by selecting the most suitable artificial lifting systems to be continued

  with a minimum need for utilizing workover rig .

- Pumping produced oil from El-Raml field to a gathering plant at Faras field via 3.5” x 4.5” pipeline

- Solving problem of El-Raml salty production to make its salt content within the accepted figures for shipping to Bapetco by using a desalting unit at Faras plant.

- Output production from El-Faras is pumped to Bapetco gathering plant via 6” & 55 km pipeline

3. DEVELOPMENT OF ZARIF FIELD

3.1 General Description

Zarif field is located in the north of Ras Qattara development lease in the western desert about 40 km south of Meleiha development lease (fig.1), the discovery well (Z-2) drilled in 1992 structurally up dip of the dry well (Z-1).

This discovery well encountered good oil and gas shown in Bahariay formation which was successfully tested at the rate of 726 bopd (28 °API) through 32/64” choke.

The appraisal phase conducted by Agiba drilling two wells (Z-3 & Z-4) in 1994, proved economical potential of Zarif field. Presently the development scheme consists of ten wells (8 oil producers, 1 water injector and 1 water source)

3.2 Characterization of Zarif reservoir

3.2.1 PVT Data

The basic oil characteristics have been taken from the PVT analysis of the well (Z-7) are :

- BP = 815 psia
- Boi = 1.63 RB/STB

3.2.2 Initial reservoir data

- OOIP is 38.83 MMSTB
- PS is 1725 psia at datum 3750' SSL

3.3 Production History

The production started in June 1994 by wells Z-2, Z-3 & Z-4 followed by Z-5 in March 1995 and both of Z-7and Z-8 in June 1995. The well Z-6 was set to water injection in October 1996 to support the pressure depletion by the produced water from water source well (Z-9) equipped with an electric submersible pump, also wells Z-11 and Z-12 were put on production stream in May 1997.

Total number of Zarif oil producing wells now is eight distributed as six, each of them is equipped with a sucker rod pumping system and two are temporally shut-in due to low productivity, present current production is 2300 bpd. Crude oil passes through a separator (5000 bfpd & 25 psi) where gas is separated and crude oil is directed to two storage tanks having 5135 barrels storage capacity, then withdrawn and is pumped to Meleiha process area using one of two triplex pumps each of 2750 bfpd and 2200 psi

3.4 Crude oil pumping from Zarif to Meleiha

One of the main factors affects on the cost per barrel while developing an oil field is the crude oil transportation. To compress this cost to the minimum limit, the available scraped tubing joints of 3.5" and 4.5" were used and a pipeline of 56 km long was constructed, first 45 km is 3.5" and last 11 km is 4.5", as shown in fig.2

Flow rate is proportional with the square root of the hydraulic friction losses in the pipeline and is limited by the maximum allowable working pressure or hydrotesting pressure (2500psi), to minimize probability of expected leakage at any point.

Problem of this pipeline appeared by winter while pumping 2600 bpd where pumping pressure reached to 2270 psi due to the excessive increase in viscosity (fig.3). To solve this problem, two options were suggested as:-

First: Reduction of crude oil viscosity by injecting a drag reducer agent in the flow stream to reduce pumping pressure .

Second: Looping part of this pipeline to realize one of two results:

- Increasing pumping flow, pumped with 2270 psi
- Reduction pumping pressure on pumping 2600 bpd

Cost analysis was performed and resulted in that the second option is the most economic one and a length of 22.72 km tubing joints was used as: (14.065 km x 4.5") & (8.655 km x 3.5")

3.4.1 Operating design parameters for original pipeline and looping

- Liquid pressure gradient is 1285.5 psi / km
- Pipe roughness is 0.005 inch
- Inlet pressure to Meleiha process plant is 50 psi
- Crude oil viscosity is 21.4 centistokes at 10 °C
- Meleiha process area is higher than Zarif field by 200 feet relative to MSL
- To cover any further losses due to elbows, valves, and other fittings. Total hydraulic losses are multiplied by 1.1

Used equations regarding design of pipeline are listed in table.1. The pipeline net work after looping is shown in (fig.4), it is shown from (fig.5) that maximum pumping pressure required to pump 2600 bpd is 1500 psi (66 % of pumping pressure before looping). By summer, pumping pressure usually decreases by ± (15-20) % due to reduction in viscosity.

4. DEVELOPMENT OF EL-FARAS FIELD

4.1 General Description

El-Faras complex is located in the north of Ras Qattara development lease in the western desert about 60 km south of Meleiha development lease (fig.1). The complex is composed of two separate fields; El-Faras and El-Mohr, separated from each other by a main fault. El-Faras reservoir lies at a depth of about 3000 feet SSL, while El-Mohr reservoir reaches 5000 feet SSL. El-Faras area was discovered in 1996 with well F-1 which encountered an oil interval (60-70) feet thick, the well was successfully tested with an oil rate of 3000 bopd (46 °API), two more wells (F-2 & F-3) encountered good mineralized intervals while well F-4 found water, oil production started in November 1996 from three wells : F-1, F-2 & F-3.

In 1997 two new wells, F-5 and F-6 initially drilled as injector wells but were completed as producers due to their good oil shows

The pressure measurements in these last wells show communication with the area of the other wells, five wells are producing now artificially from El-Faras; F-1, F-2, F-3, F-5 and F-6.

The only well with water problem (W.C is 50 %) is F-2, Total OOIP for El-Faras complex is 89.5 MMSTB and is subdivided into; 86.7 MMSTB in El-Faras field and only a small amount as 2.8 MMSTB in El-Mohr field. Which was discovered in 1992 with the perforation of well El-Mohr-1 which was put on production in April 1997 and very quickly experienced water problems (W.C is 75 % in August 1998). Another well (El-Mohr-2) was drilled in 1995 but found water producer confirming limited extension of this area

4.2 Geological Description

The wells drilled in El-Faras field confirmed the general lithostratigraphic subdivision characterizing the Western Desert area. They crossed the Albian Cenomanian sequence encountering, starting from bottom to top the following formations:

- Kharita formation
- Bahariya formation
- Abu Roash formation “G” member

The formations are arranged in fining upward trend according to the regional regime that occurred at that time. The hydraulic bearing pools of the field belong to the upper part of the Bahariya formation while the rest of the sequence was found shaly or water bearing except for a small hydrocarbon oil column encountered in the Abu Roash “G” member by the well F-1

4.3 Stratigraphy

The subdivision used in the western desert area can be applied at field scale for well to well correlation’s and for internal reservoir characterization. The general description of the formations constituting the Albian-Cenomanian sequence as:

- **Kharita formation**

Constituted by massive sand bodies with thickness ranges from meters to ten meters interbeded with thin shaly intervals

- **Bahariya formation**

This formation is split into two different faces associations represented by the lower and upper Bahariya respectively, the lower Bahariya face is characterized by thick sandstone intervals inter-bedded with shale with medium to low lateral continuity at field scale, the upper Bahariya face is represented by thinner and finer sandstone beds inter-bedded with shales .

- **Abu Roash formation “G” member**

This formation Is constituted by shale and limestone

5. EL-RAML AND EL-FARAS FIELDS DEVELOPMENT PLAN

5.1. Artificial lifting system

The points taken into consideration while proposing artificial lifting methods to put El-Raml and El-Faras fields on production stream are:
- Remoteness and topography of fields area
- Power availability and simplicity of operations mode
- Expected work-over frequency
- Flexibility of expanding the system according to the future development plan

5.2. Evaluation of different artificial lifting options

An evaluation is made for the possible artificial lifting to be applied in this remote area as shown in table.2

Item of comparison	Electric Submersible Pump	Sucker rod pump	Jet pump
Flexibility	- Runs at fixed speed & requires careful sizing - Variable speed is suitable but needs additional cost	Stroke per minute, stroke length & plunger size could be changed to control production rate	Selection of throat & nozzle combination extends range of volume and capacity
Down hole equipment	Good operating practices is essential	Good rod design	- No moving parts - Long service life - Simple repair procedure
Operating cost	- High with increasing required driving power - High costs of repair	Very low for shallow and medium depth (7500')	Low pump maintenance but high cost with high required power
Reliability	- Very sensitive to operating & electrical malfunctions - Requires a good power Source	Excellent if good operating practices are followed	Good with proper sizing
Miscellaneous	- Needs rig for work-over - Requires a high reliable electric power system	- Does not need rig - Needs auxiliary pump of 20 horsepower	- Does not need rig - Needs auxiliary pump of 20 horsepower

Table.2 Comparison between different artificial lifting systems

Development plan was carried out using sucker rod pumps and jet pumps, as they represent the most suitable artificial lifting systems, present production modes are distributed as follows:

El-Faras field: jet pumping system (three wells) and sucker rod pump (three wells)
El-Raml field : sucker rod pump (three wells) and two wells are producing naturally

Present production rates of El-Faras and El-Raml fields are 4230 and 2230 bopd respectively.

5.3. Surface production facilities

Present production facilities in both El-Raml and El-Faras fields were designed to facilitate gas-oil separation process and for crude oil pumping from El-Raml to El-Faras it is desalted in El-Raml down to the allowable salt content figure for shipping to Bapetco (24 PTB), used facilities are shown in table.3

Production facility	El-Raml	El-Faras
Three-phase separators - Flow rate, bfpd - Operating pressure, psi	 5000 25	 10000 75
Desalter - Capacity, bopd	 -	 10000
Storage tanks - Nominal capacity, bbls - Actual capacity, bbls	 (2x600) + (1x500) + (1x1200) (2x450)+ (1x420) + (1x900)	 (1 x 5000) + (1 x 5000) (1 x 4800) + (1x 4800)
Transfer pumps - Number - Maximum operating pressure each, psi - Maximum flow rate of each, bpd	 2 1587 4338	 2 1400 14000

Table.3 Production facilities in El-Faras and El-Raml fields

5.4 Crude oil handling across El-Raml & El-Faras fields and Bapetco

5.4.1 Crude oil pumping from El-Raml to El-Faras

To make good use of the available tubing, the pipeline suggested to transport crude oil from El-Raml field to El-Faras field is composed of (25.5 km x 3.5") and (10.5 km x 4.5"), design parameters are :-

- Liquid pressure gradient is 1226.6 psi / km
- Inlet pressure to El-Faras process plant is 25 psi
- Crude oil viscosity is 15.5 centistokes at 5 °C
- El-Raml area is higher than El-Faras area by 9 meters relative to MSL
- Pipe roughness values are 0.006" & 0.008" for tubing sizes; 3.5" and 4.5" respectively
- Total hydraulic losses are multiplied by 1.1 as tubing joints are rough and to cover any further losses due to elbows, valves and other fittings

The pipeline was tested up to 2200 psi. From fig.(6) it is seen that the capability of this pipeline is not sufficient to handle over 4000 bpd where maximum pumping pressure is 2400 psi. For handling the expected increase in production from this field, it will be necessary to make looping for some length of this existing pipeline in future. By summer, pumping pressure usually decreases by ± 10 % due to reduction in viscosity

5.4.2 Crude oil pumping from El-Faras to Bapetco

Crude oil of El-Raml and El-Faras fields is pumped from El-Faras field to Bapetco, current pumping flow rate is ± 7000 bpd and pumping duration is ± 12 hours daily, parameters used in the design of the trunk pipeline, 55 km x 6" (nominal size) are:

- Liquid pressure gradient is 1208.3 psi / km
- Crude oil viscosity is 7.3 centistokes at 37 °C
- The pipeline material is API 5 L X 52, not coated and is not buried
- Pipe roughness is 0.005"
- Bapetco is higher in elevation than El-Faras by 70 meters relative to MSL
- To cover any further losses due to elbows and valves, theoretical hydraulic friction losses are multiplied by 1.05 factor
- Maximum pumping pressure is ± 1400 psi on pumping ± 14000 bpd

Used equations in articles 5.4.1 and 5.4.2 are stated in table.3

6. CONCLUSIONS

- Carefully study for pipeline looping (position and length) solved problems of pumping viscous crude oil specially in cold weather
- Proper selection of the suitable artificial lifting systems helps in cost optimization for the cost per barrel
- Early and permanent production started successfully using nearest available facilities.

7. TECHNICAL CONTRIBUTIONS

Actions and related procedures to solve encountered problems in the development of the subject fields might be applied for other similar situations.

8. NOMENCLATURES

Z	:	Zarif
BP	:	Bubble point pressure
Boi	:	Initial oil formation volume factor
RB	:	Reservoir Barrel
STB	:	Stock Tank Barrel
OOIP	:	Original Oil In Place
MM	:	Million
PS	:	Static Pressure
MSL	:	Main Sea Level
SSL	:	Sub sea level
bpd	:	barrel per day
bfpd	:	barrel fluid per day
H_f	:	Hydraulic friction loss
Q	:	Flow rate in thousand barrels per day
F	:	Faras
W.C	:	Water Cut
R	:	Raml
PTB	:	Pounds per Thousand Barrels

9. ACKNOWLEDGMENT

The author wishes to thank Agiba petroleum co. represented in its chairman and operations manager for their help, continuous encouragement and their permission to publish this paper, also he thanks staff of petroleum engineering for the valuable help in finalizing this work

10. REFERENCES

- El-Faras 3 D reservoir model study, Agiba petroleum co., September 1998
- Zarif reservoir model study, Agiba petroleum co., November 1996
- Moody chart for determination hydraulic friction loss factor

11. SI METRIC CONVERSION FACTORS

in x 2.54´ E+ 01 = mm
ft x 3.048´ E– 01 = m
bbl x 5.615 E+ 00 = ft^3
psi x 6.894 757 E+ 01 = kPa
Centistokex1.0 E - 02= cm^2/s
Psi/ft x 3.048 E - 04= psi/km
141.5 / (131.5+°API) = g/cm^3
F (°F–32) / 1.8 = °C
´ Conversion factor is exact

Pipeline	Outer Diameter, inch	Internal Diameter, Inch	Reynolds Number	H_f, psi / km
Zarif / Meleiha	3.5 4.5	2.992 3.958	1440.8 Q 1089.2 Q	156.113 f Q^2 38.535 f Q^2

Table.1 Used equations in design of pipeline systems in Zarif field

Pipeline	Outer Diameter, inch	Internal Diameter, Inch	Reynolds Number	H_f, psi / km
El-Raml / El-Faras	3.5 4.5	2.992 3.958	1989.2 Q 1503.7 Q	148.9 f Q^2 36.7 f Q^2
El-Faras / Bapetco	6.625	5.937	2128.6 Q	4.554 f Q^2

Table.4 Used equations in design of pipeline systems in El-Raml & El-Faras fields

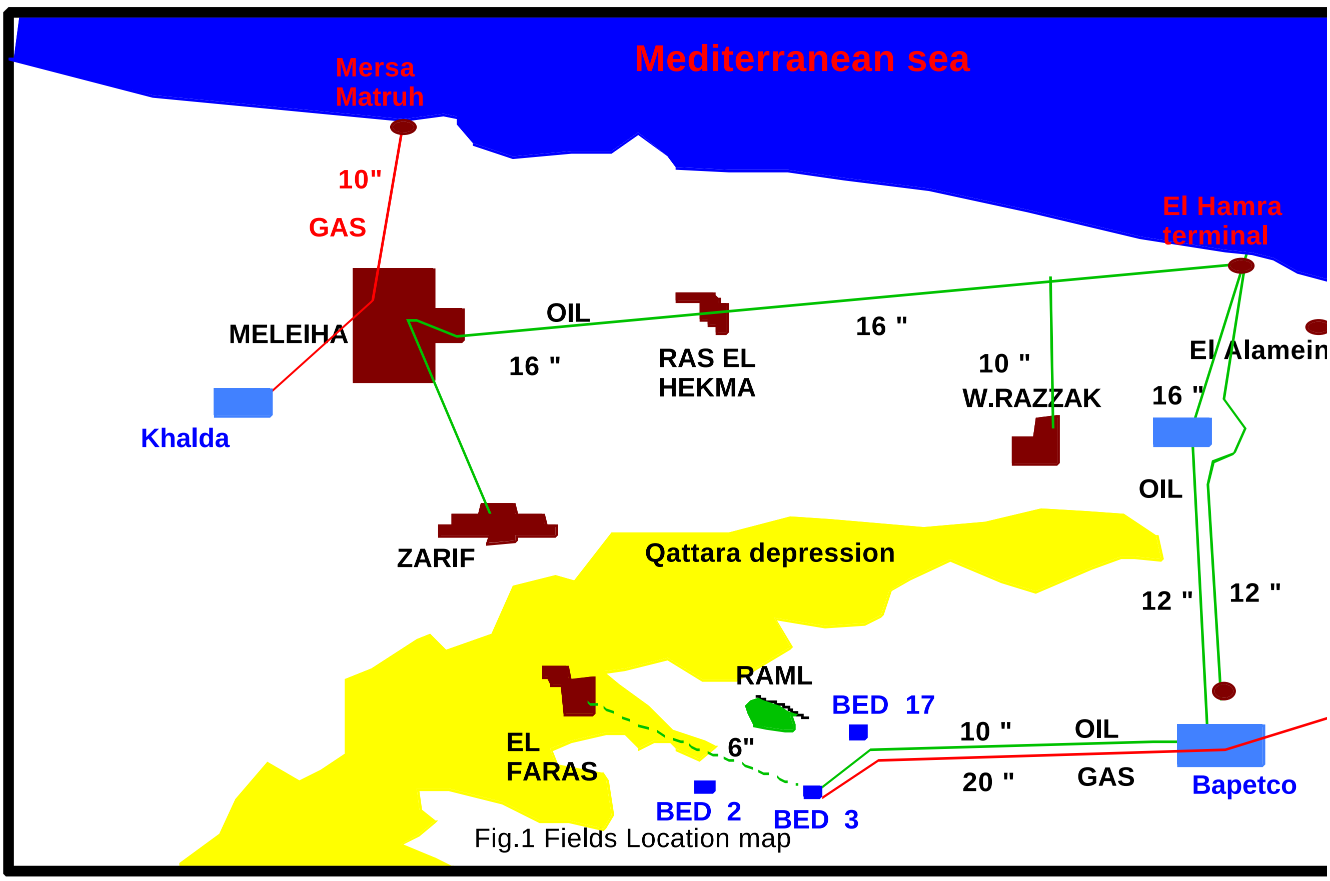

Fig.1 Fields Location map

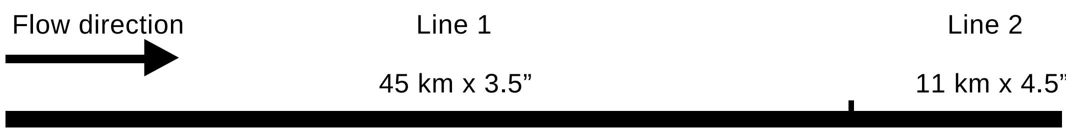

Fig.2 Zarif / Meleiha pipeline network before looping

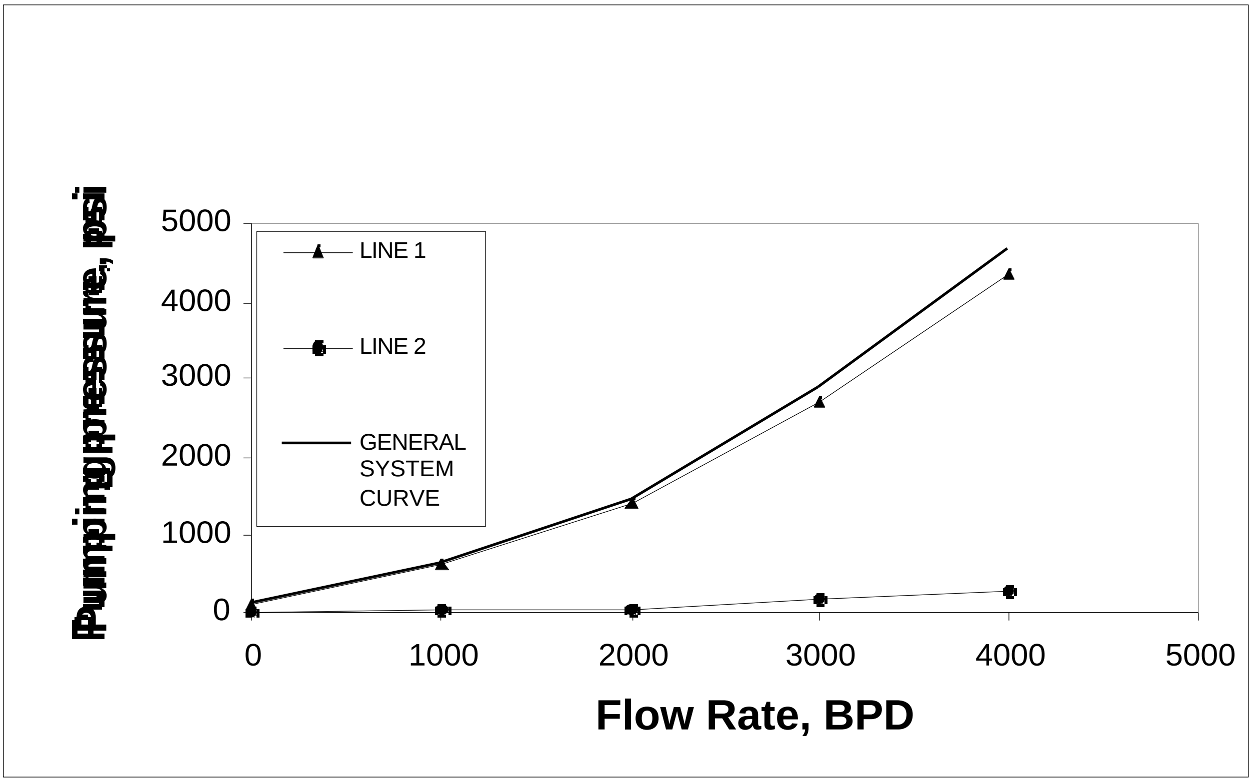

Fig.3 Characteristic curves of Zarif/ Meleiha pipeline before looping

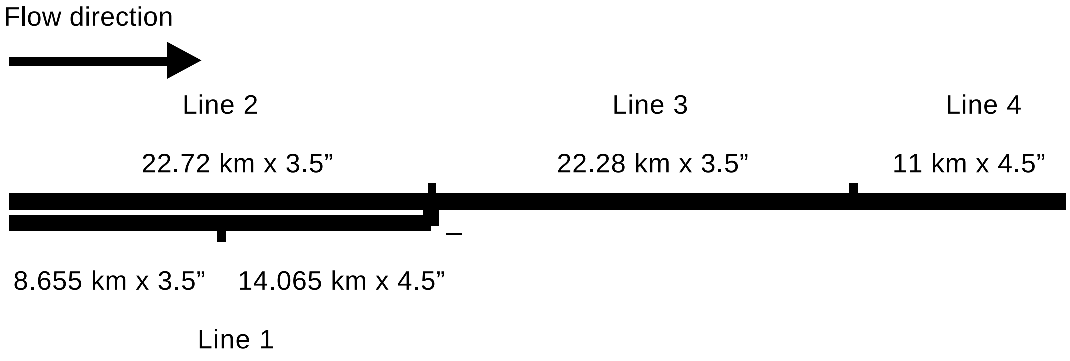

Fig.4 Zarif / Meleiha pipeline network after looping

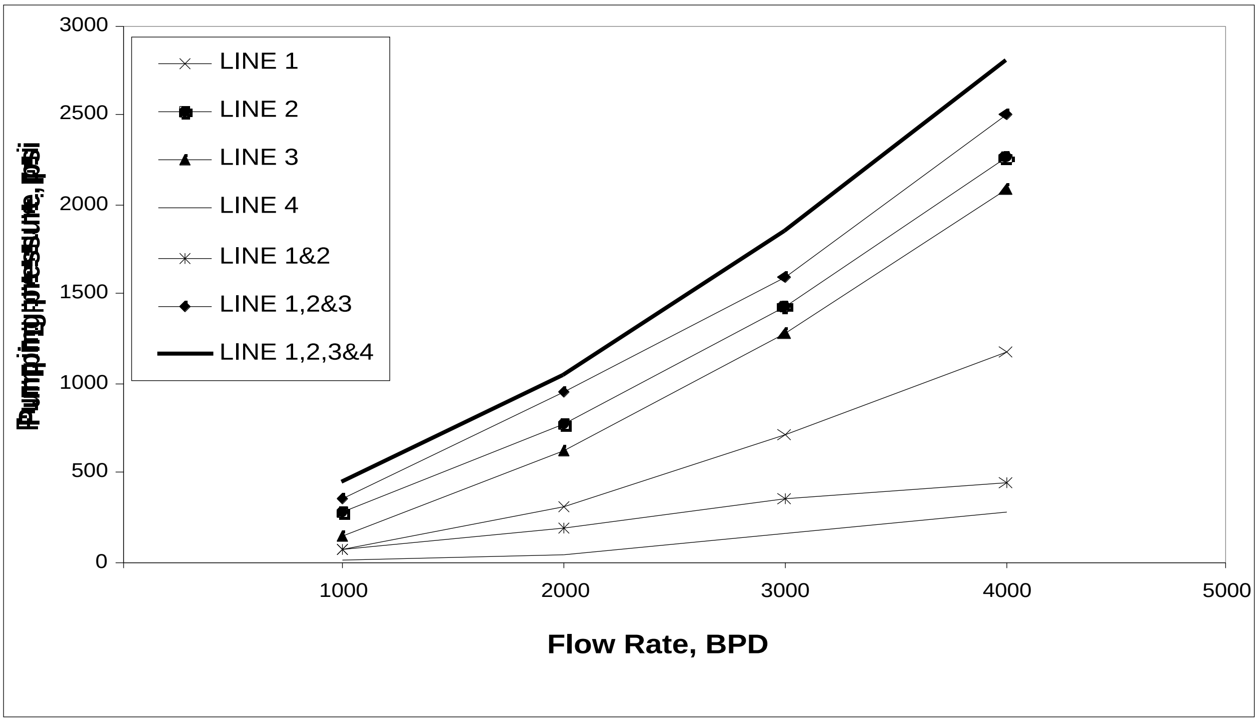

Fig.5 Characteristic curves of Zarif / Meleiha network after looping

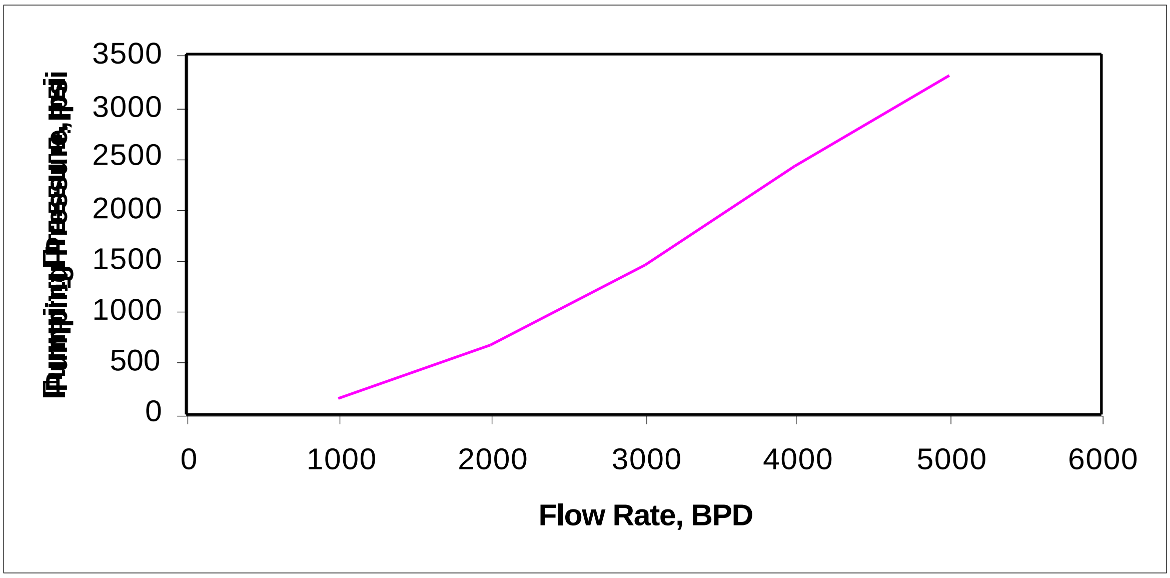

Fig.6 Characteristic curve of El-Raml / El-Faras pipeline