APPLICATION OF NATURAL GAS-POWERED ELECTRICAL GENERATORS TO REDUCE POWER COSTS

Jon Hale
Apache Corporation
Doug Hoitenga and Bill Heard
Engine World, Inc.

Introduction

The single largest operating cost in the Permian Basin is electrical power due to the widespread use of waterflooding and/or high volume artificial lift. In most cases, operators with large power loads can receive preferential industrial power rates in order to lower their power costs. However, in cases where smaller power loads exist or preferential rates are not an option, the operator must investigate other options to lower its power bill. One option currently being tested is the use of natural gas-powered generators, which can generate the electrical power on-site that is necessary to run oilfield equipment using either residue or lease gas, and in turn lower your power costs significantly.

The Niche of Electrical Generators in the Oilfield

As with most industries, electric power in oilfield applications has been supplied in large part by utilities ranging from major providers such as TXU Electric and New Century Energies (formerly Southwestern Public Service Company) to rural electric co-operatives (REC), which are widespread across the Permian Basin. The major providers not only supply power but also have their own generation capabilities. This has allowed the major electric utilities to offer preferential industrial rates for large loads (> 1 MW), such as interruptible rates, as low as $0.03 per kWh. However, the RECs typically buy their power from the major providers since they do not have their own generation capabilities. In essence, they act as a middleman and can not offer industrial rates as low as the major providers. This situation for the RECs has allowed for the advent of on-site gas-powered generators. Furthermore, utility power is still unavailable or impractical in certain areas. These include mobile operations such as drilling rigs and remote operations where it is cost prohibitive to run transmission and distribution lines. In these instances, small (< 1 MW) generators have been used quite effectively.

The use of generators in the oilfield is nothing new. As noted above, every drilling rig has some kind of generator to supply electricity. However, using generators for primary power in fixed installations is a rather recent development. More efficient generation units, such as POWR/MASTR, can bring them to a level competitive with utilities. On-site generation may result in power rates of $0.04 to $0.06 per kWh compared to some utilities that charge $0.06 to $0.10 or more per kWh. Primary power generators start to look attractive for these applications.

Another major development in the electric utility industry is the sweeping changes that will be brought about as a result of deregulation. The Texas Legislature has approved electric industry deregulation, which will be implemented on January 1, 2002. This new law will allow consumers the freedom of choice when providing for their power needs. In the past, consumers were "locked in" to the electric utility that served their area. In the future, consumers will be able to negotiate with retail electric suppliers to provide for their energy needs at a competitive price.

There are many underlying issues resulting from deregulation but one issue that directly affects on-site generation is infrastructure. There is little likelihood of new coal-fired, oil-fired, nuclear or hydroelectric power plants being built in the United States. Even if they are not banned outright by environmental concerns, the hurdles involved will be too burdensome to be economic. Gas-fired power plants will probably be the only new plants built and they may not be able to keep up with demand. A recent study by the INGAA Foundation predicted that distributed generation (power generated on- or near-site) has the potential to provide 20% of the additional generating capacity in the United States over the next 20 years. Furthermore, it is estimated that as much as 25% of the present power generating capacity of the U.S. will be decommissioned in the next 10 to 20 years. Also, transmission and distribution lines in many areas are overloaded. Replacement of these lines will be at a tremendous cost. This may not impact all oilfields but it is sure to affect some. As a result, the advent of on-site power generation will play a larger role in the future of electric power supply.

Whv Use Natural Gas-Powered Electrical Generators?

In late 1998 and early 1999, oil prices had dipped to the $8 to $9 per barrel range and many operators were looking at ways to reduce their operating expenses. One of the areas Apache Corporation focused on was electric power cost, since it represented the largest single operating expense in the Permian Basin for Apache, as well as many other operators. As part *of* this power cost reduction effort, on-site gas-powered electrical generators were investigated but frankly were not a proven reliable application for widespread use and, in many cases, did not provide significant enough savings to warrant serious consideration. However, this opinion changed when Engine World introduced the POWR/MASTR generation unit in early 1999.

POWR/MASTR Specifications

POWR/MASTR units offer many of the features as other electrical generators but also contain many advantages over other units.

- Electrical Output: 80 kW continuous load (100 kW max at sea level)
  Varies based on location, altitude, humidity, and temperature constraints
- Engine Design: **7.4** liter General Motors industrial short block converted for natural gas consumption

- Fuel options: natural gas, propane, butane, methane
  produced gas – to a limited degree (depends on contaminants)
- Fuel Efficiency: 9 to 13 therms per hour to produce 100 kW (at sea level)
  1 therm = 100,000 BTU
- Operating Life: Engine operates at 2228 RPM to reduce engine load and increase operating life to five (5) continuous years.
  Many other industrial engines operate at 2400 to 3600 RPM.
- Controls Programmable Operating Control System (POCS) allows for load sharing (synchronization) between utility or multiple units.
  Also, allows for remote-access monitoring or programming.
- Modularity: ability to link several units together (synchronize and load share) to handle large loads. Also, allows for regular service and maintenance without taking a large amount of capacity off line.
- Synchronous Generator: Permanent Magnet Generator (PMG) allows for stand-alone operation and does not require connection to utility for winding excitation
- Environmental: at present, no air permits required for individual unit (exempt)
  no tanks required for liquids (no fuel spills)
  60 dB noise level at 30 feet
- Weight: 4200 pounds
  a well known competitor's 100 kW unit weighs 9000 pounds.
- Portability: moved on its own special dolly
  competitor's unit requires a crane to set
- Leveling system: sets on four legs, each with independent jacking system
  Unless required by local regulations, it does not have to set on one large concrete pad (savings on installation cost).
- Dimensions: *8* feet long by 5 feet wide by 6 feet tall

The main disadvantage of POWR/MASTR units is that only one output power design is currently available (100 kW). This severely limits the variety of oilfield applications they could be used for, especially those involving most pumping unit installations. Furthermore, there are some limitations involving the use of produced gas as fuel. The produced gas needs to be somewhat free of contaminants (H2S, CO2, and N2) or corrosion problems can occur, as well as excessive heat and engine "knocking". These problems were experienced in the test case on the Good #14 and will be discussed in more detail later.

POWWMASTR Lease Arrangement

The lease terms of the POWR/MASTR unit are what separate it from other generation units. Each 100 kW POWR/MASTR unit leases for $1,500 per month for a term of 60 months. The monthly lease includes installation of the unit(s) as well as maintenance, which is performed on each unit at 1500-hour intervals. Insurance is provided optionally at $50 per month per unit, which covers any catastrophic event, such as fire, that either damages or destroys the generation unit. Furthermore, the lease also has a downtime provision whereby POWR/MASTR will replace any unit which experiences 72 hours of continuous downtime.

Candidate Selection Criteria

When Apache was presented with the opportunity to save on its electric bills by using POWR/MASTR units, a process was initiated to select potential candidates. Several criteria were investigated in order to select the best overall candidates for the project to be successful:

- Fairly significant load – Apache narrowed its search to submersible pump installations, since only 100 kW units were available and the largest incremental savings could be realized with greater loads.
- High cost electric power – Apache identified properties that were averaging at least $0.05 per kWh, which happened to correspond with most RECs.
- Produced gas volume – Leases were identified that produced enough gas to supply one or multiple units, as it was determined the greatest economic benefit could be achieved when using produced gas as fuel.
- Gas analysis – Analyses were gathered to investigate the amount of contaminants present and whether they were acceptable to use produced gas as fuel.
- Economic life – Each candidate was reviewed to determine its economic life since the POWR/MASTR lease requires a five-year commitment.
- Inability to negotiate with utility – Before committing to a long-term lease arrangement for on-site generators, efforts were made to negotiate with the existing utility but they were either unwilling or unable to offer competitively lower power rates.

Good #14 Candidate Selection

After considering the criteria for candidate selection, the Good #14 was selected as an excellent test candidate for POWR/MASTR generators. The Good #14 is a Canyon producer located in Borden County, Texas. The well is pumped with a 195 HP slimhole electrical submersible pump (ESP) set at 7790 feet, inside 5" production casing. In addition, a variable speed drive (VSD) is installed, running at 75 hertz. Currently, the Good #14 is testing at 29 BOPD, 1935 BWPD, and 40 MCFD, with a fluid level above pump (FLAP) of 897 feet. The current test rate is the maximum rate that can be achieved by the current slimhole ESP design.

Based on utility invoices from Cap Rock Electric, the power bill for the Good #14 has averaged $11,199 per month for the first 10 months of 1999 (see Attachment 1). The monthly electrical usage has been 172,800 kWh, which equates to a power rate of $0.065 per kWh, considered to be fairly high. Furthermore, the Good #14 is metered and invoiced separately, so the usage and invoice amounts are exact. Based on the monthly kWh usage, the power load equates to 237 kW, which would require three (3) POWR/MASTR units to provide electricity on a continuous basis.

Apache decided to use produced gas from the central tank battery (CTB) to fuel the

POWR/MASTR units, since the CTB is relatively close to the Good #14 well site and an excess of gas would be available at the CTB. A recent gas analysis was reviewed to determine the amount of contaminants (H_2S, CO_2, and N_2), as well as other physical properties (see Attachment 2). The analysis indicates 4.818% contaminants, which was in the acceptable range. However, the main concern was the H_2S concentration of 800 PPM, a little high but still at an acceptable level. The BTU content was 1716 on a dry basis, while methane represented slightly less than 50 mole percent. During the preliminary stages, it was thought this rich produced gas would serve as a good fuel gas for the generators. However, several problems were encountered during the testing process related to the heavier components burning at varying temperatures and resulting in engine "knocking" and excessive heat.

The final step in selecting the Good #14 as a test candidate for POWR/MASTR generators was the economics depicting the prospective savings that could be achieved versus the existing utility power costs. The monthly lease of $4,500 for three (3) POWR/MASTR units and optional insurance of $150 per month were considered fixed costs. The fuel cost was variable, as the produced gas value can fluctuate dependent upon the gas price. Several scenarios were run for the fuel cost, varying the gas price from $1.67 per MMBTU, which is the price Apache received for the gas during the first 10 months of 1999, up to $3.00 per MMBTU (see Attachment 3). At $1.67 per MMBTU and using 65 MCFD produced gas for fuel, total costs to operate three (3) POWR/MASTR units was $7,952 per month, which equates to a power rate of $0.046 per kWh. This resulted in prospective savings of $3,247 per month, a reduction of 29.0% versus the utility power costs. Thus, the prospective savings are considerable if the POWR/MASTR units prove to be functional and reliable. At a gas price of $3.00 per MMBTU, total costs increased to $10,581 per month or a power rate of $0.062 per kWh. Prospective savings decreased to $617 per month, a 5.5% reduction versus the utility power costs. If gas prices increase to the $3.00 per MMBTU level or slightly higher, the economics are not as favorable for the POWR/MASTR installation and should be a long-term consideration for the project.

Installation and Testinq of POWR/MASTR Units on Good #14

Engine World initially installed three (3) POWR/MASTR generation units at the Good #14 well site in late June 1999. The generation units were wired to a fused disconnect and contactor box, together known as a control panel. Apache laid a polyline for produced gas supply from the Good CTB to the #14 well site, approximately one-quarter of a mile distance. In addition, a filter separator unit was installed on the gas inlet of the generation units, to help drop out condensation from the produced gas. The units' controls were programmed for synchronization and load sharing, and then tested with a load bank, which simulates the electrical load requirements of the well. Under initial testing of the well itself, the units shut down with high temperature conditions in the gearbox and control cabinet. Furthermore, the units experienced pre-detonation or "knocking" in the engine cylinders. During initial testing, it was noted the units' averaged 95 kW power capacity each, but were unable to maintain this capacity under continuous (24/7) load conditions. Distributor timing adjustments on the units were unable to completely eliminate the engine "knocking". At this time, the heat problems were attributed to the high BTU produced gas, as well as complications by running the ESP through a VSD.

Engine World installed a fourth POWR/MASTR unit, free of charge, to distribute the load requirements of each unit. With four generators hooked up (see Attachments 4 – 8), additional load bank testing was performed. The generators again ran the well for 84 continuous hours, before one generator dropped out and would not carry its load. The engine teardown revealed that one piston was damaged, again attributable to the high BTU produced gas. Also, it was determined the stock aluminum piston design was not good for this application.

Engine World initially experimented with lower compression cylinder heads, which ran fine but only produced 75 kW power capacity from each unit. Engine World replaced the stock pistons with a different design on one unit, and then ran the generation unit for 80 hours under load bank simulation. The unit produced 95-100 kW capacity during this test. A subsequent teardown of the engine revealed no head or piston damage. This led to the installation of rebuilt engines with different piston design for the three (3) remaining POWR/MASTR units. At the time of publication for this paper, load bank simulation tests are being performed on all four **(4)** units for a two-week period. Upon satisfactory results, it is expected the well will be placed on the POWR/MASTR units around January 1st, 2000. Updated results of the POWWMASTR units' performance will be documented and presented in further detail at the Southwestern Petroleum Short Course in April 2000.

Conclusions/Considerations

1. Most of the high-cost power rates (> $0.05 per kWh) will be associated with the rural electric co-operatives. Check with your utility to determine if rate options exist to lower your power bill.
2. Electrical generators are single-well/facility applications and can be limited on their variety of power output ratings. Focus your selection **of** generator candidates to medium-to-large power loads (> 80 kW).
3. Determine if enough produced gas is available to fuel the generator(s) (25 MCFD per unit). Review your gas analysis to determine the amount of contaminants (H_2S, CO_2, and N_2), the component breakdown, and the BTU content. Consider the use of residue gas if available.
4. Review the long-term economics of your well before committing to a five-year lease. Will the well be uneconomic in five (5) years? If produced gas is being used as fuel, will gas prices exceed $3.00 per MMBTU during the next five (5) years? What will be the impact when deregulation occurs January 1, 2002?
5. Electrical generators can provide significant power savings where the utility costs exceed $0.05 per kWh on a medium-to-large power load. But can generators provide the reliability that the utilities have historically demonstrated?

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Bibliography

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3. Harris, Billy and Ennis, Pat: "Deregulation, Technology Bringing Opportunities For Power Cost Reduction." Petroleum Engineer International (September 1999)

Good #14
Electric Utility Costs

Billing Date	kWh Used	Cap Rock Bill	Power Rate $/kWh
2/10/99	169280	$ 10,599.42	0.0626
3/11/99	168960	$ 10,737.34	0.0635
4/12/99	187840	$ 11,818.10	0.0629
5/11/99	165120	$ 10,689.25	0.0647
6/10/99	174720	$ 11,274.48	0.0645
7/12/99	182400	$ 12,233.49	0.0671
8/10/99	129600	$ 9,435.37	0.0728
9/9/99	180480	$ 11.383.99	0.0631
10/8/99	175360	$ 11,532.13	0.0658
11/9/99	194240	$ 12,282.59	0.0632
1999 Total	**1,728,000**	$ **111,986.16**	**0.0648**
1999 Average	**172,800**	$ **11,198.62**	**0.0648**

Note: Well site is metered separately, thus reflecting kWh and electric costs as determined by Cap Rock Electric.

Attachment 1

Good Lease Gas Analysis			
Component	**MOL %**	**GPM**	**WT %**
Hydrogen Sulfide	0.080		0.088
Carbon Dioxide	0.887		1.260
Nitrogen	3.851		3.483
Methane	49.994		25.894
Ethane	14.222	3.783	13.807
Propane	15.886	4.354	22.616
!so-Butane	1.939	0.631	3.639
N-Butane	6.861	2.151	12.875
Iso-Pentane	1.717	0.625	3.999
N-Pentane	1.886	0.679	4.393
Hexane Heavier	2.677	1.089	7.946
Total	**100.000**	**13.312**	**100.000**

Calculated Physical Properties @ 14.65 psia & 60 deg F:

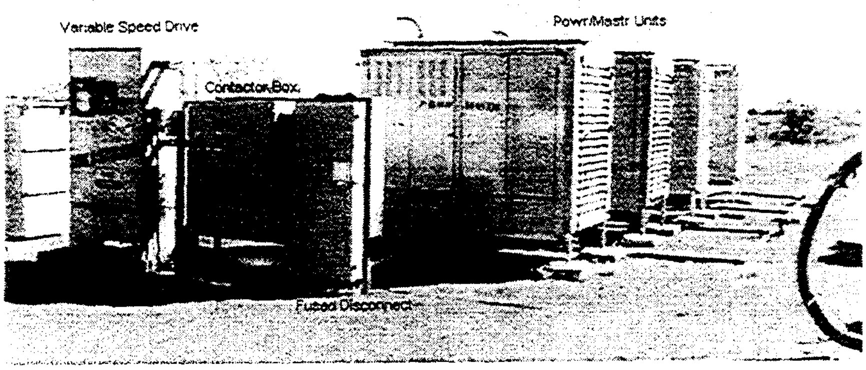
Sp. Gr. (Air = 1)	1.066	BTU wet basis	1686.013
Cp	0.451	BTU dry basis	1715.869
Mol. Wt.	30.974	Critical Temp. R	492.039
Accentric Factor	0.081	Critical Press.	639.501
Cp/Cv	1.166	28# GPM	3.661

Attachment 2 - Gas sample taken and analyzed by Texaco E&P (gas purchaser) on 9/21/99

GOOD #14 POWR/MASTR INSTALLATION PROSPECTIVE SAVINGS							
Gas Price $/MMBTU	**Monthly Lease (3 Units) $/Mo.**	**Insurance $/Mo.**	**Fuel Cost @ 65 MCFD**	**Total Cost $/Mo.**	**Power Rate $/kWh**	**Prospective Savings($/Mo.)**	**% Reduction**
$ 1.67	$ 4,500	$ 150	$ 3,302	$ 7,952	$ 0.0460	$3,247	29.0%
$ 2.00	$ 4,500	$ 150	$ 3,954	$ 8,604	$ 0.0498	$2,594	23.2%
$ 2.50	$ 4,500	$ 150	$ 4,943	$ 9,593	$ 0.0555	$1,606	14.3%
$ 3.00	$ 4,500	$ 150	$ 5,931	$ 10,581	$ 0.0612	$617	5.5%

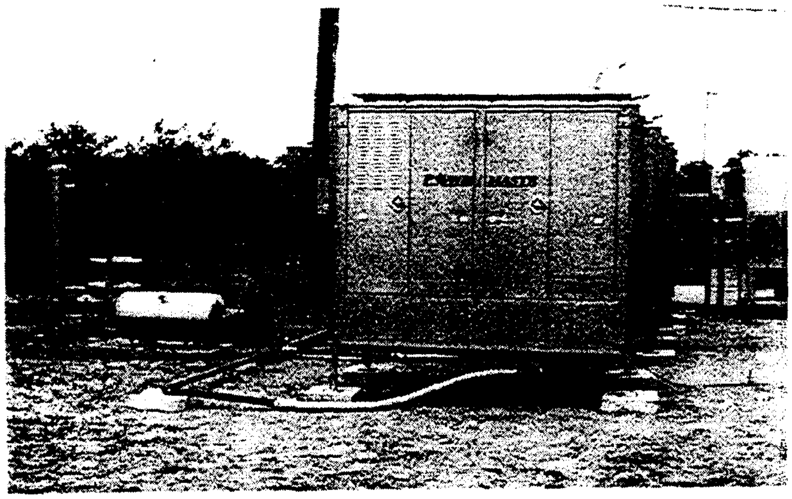
Utility Average Power Bill	$	**11,198.62**	**per month**
Utility Average Monthly Load		**172,800**	**kWH**
Utility Average Power Costs	$	**0.0648**	**per kWH**

Attachment 3



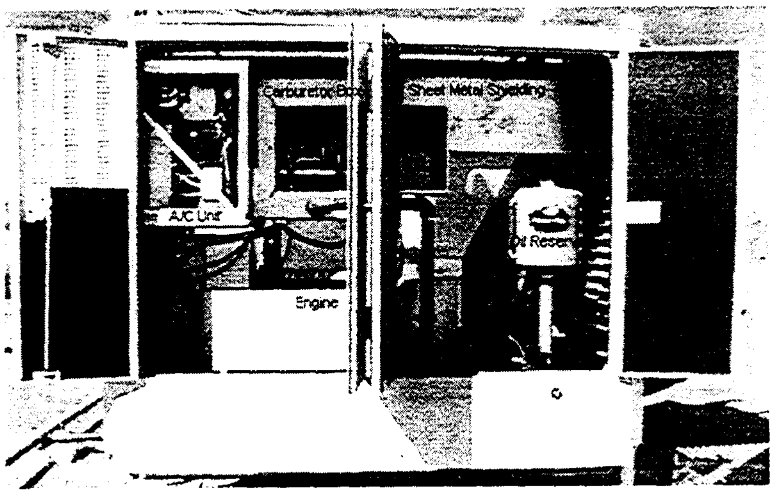
Attachment 4 - Good #14 Generator Installation

Four Generator Units and Electrical Controls
Tie into Variable Speed Drive.

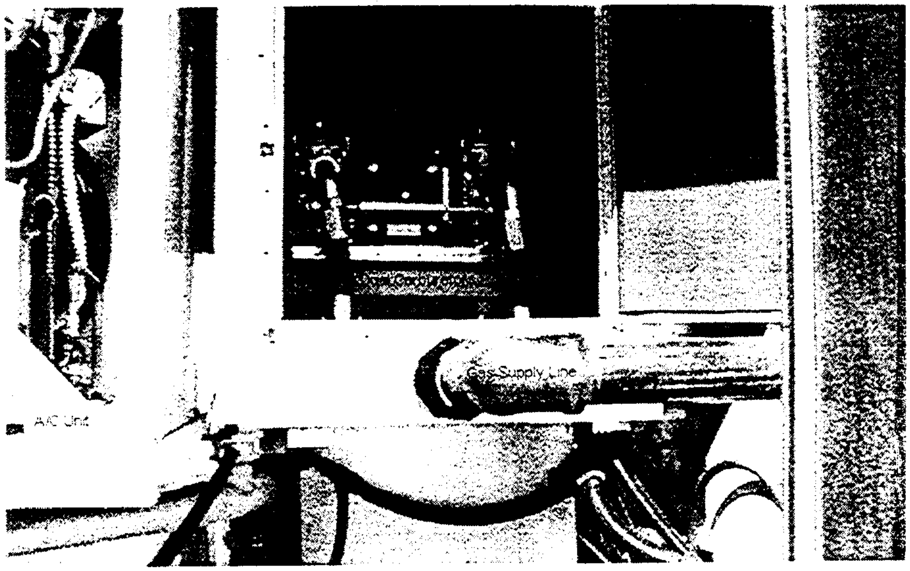


Attachment 5 - Good #14 Generator Installation

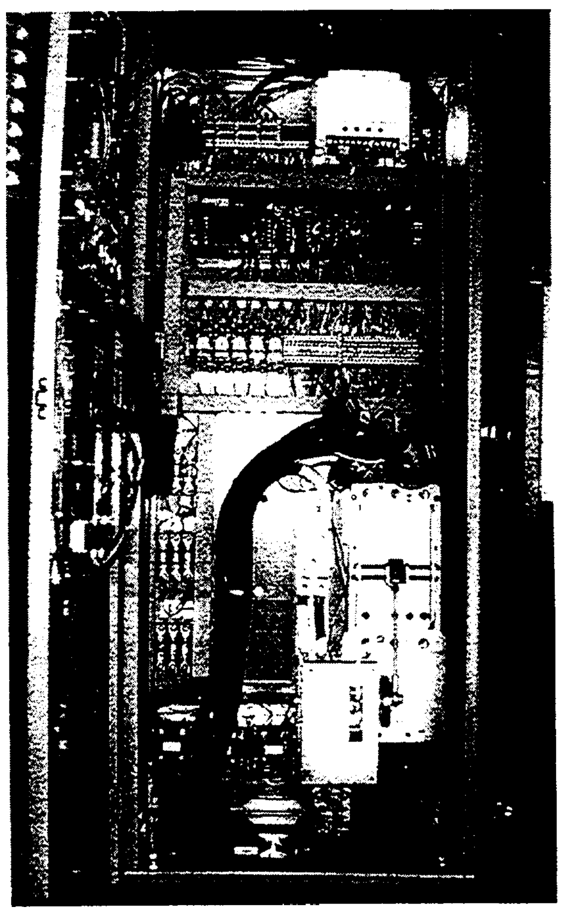
Shows Filter Separator that Removes Liquids from
Produced Gas Prior to Engine Inlet



Attachment 6 - View of Interior of Powr/Mastr Unit Showing Engine,
A/C Unit, Carburetor, Sheet Metal Ducting and Oil Reservoir



Attachment 7 - Close-up of Carburetor Box
Inside Powr/Mastr Unit



Attachment 8 - View of Inside Control Panel Showing
Programmable Operating Control System
(POCS)