No men within 50 miles: But Tapline's portable, radio-controlled, gas-turbine pumping units move oil across Saudi Arabia.

The investment: One sixth that of a community-type station in that barren desert.

GAS TURBINES in the Arabian Desert

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The Trans-Arabian Pipe Line Company has placed into operation six new pumping units driven by 5000-hp General Electric combustion gas turbines. These units, together with the original pumping equipment driven by diesel engines, provide the power to move 450,000 bbl per day of crude oil a distance of 754 miles through a 30-31-in. pipeline from Qaisumah, Saudi Arabia, to a tanker-loading terminal on the Mediterranean coast near Sidon, Lebanon.

The new units are of two types: Portable prefabricated units for unattended operation at intermediate sites; and permanently installed units at existing stations. Fig. 1 shows the turbine van and the control van of a portable unit (known as an auxiliary) as installed for operation. The Trans-Arabian system has three of these unattended units, while the Arabian American Oil Company (Aramco) has two similar units on its 270-mile line feeding crude oil into the Tapline facilities at Qaisumah.

Original System

The original Tapline system, as completed in December, 1950, had four diesel-engine-driven pumping stations spaced about 160 miles apart, which provided an initial capacity of 320,000 bbl per day. Each of these main stations is a complete community in the vast and barren Arabian desert. The desert climate is characterized by extremely low rainfall and by summer temperatures reaching 120 F and winter temperatures dropping to 30 F.

Each community installation includes housing for 80 to 250 employees, a community center with a dining hall, commissary, and recreational facilities, warehouses,
The Unattended Unit

The most attractive scheme to increase capacity involved the installation of one 5000-hp unattended pumping unit at each intermediate location. The simple-cycle combustion gas turbine was the only prime mover which satisfied the unique design requirements for these auxiliary units. The requirements were:

1. 5000-hp output for continuous operation at 110 F ambient temperature and 2600-ft elevation.
2. Prime mover to be fueled with crude oil taken directly from the pipeline.
3. Unit to be suitable for unattended operation with supervisory control from base stations 50 to 100 miles away.
4. Unit to be portable to permit rotation and major overhauls at a central shop.

The International General Electric Company was the

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4 Average annual output, 6000 bhp.
successful bidder for supplying both the auxiliary pumping units and the permanently mounted turbines for the base stations. The auxiliary pumping units were completely prefabricated and factory-tested in the United States. They were then shipped to Saudi Arabia, hauled overland to the job site, slid onto concrete foundations, and connected to pump oil. The major work of installation was completed by Jan. 1, 1958.

This is the first time that a main-line oil pump has been driven directly at gas-turbine speeds; the speed range of 5000-6000 rpm is considerably higher than that commonly used for oil pumps. This is the first time that a complete 5000-hp pumping unit has been prefabricated and made wholly portable. Also, this is the first time that a gas-turbine pumping unit has been operated unattended and by remote control.

Investment per Horsepower

Fig. 2 shows an unattended unit. A comparison of the extensive facilities at a typical diesel station (a miniature city) with the minimum facilities at an unattended unit presents a vivid contrast. Yet the hydraulic horsepower delivered to the pipeline by either installation is the same.

The installed cost of an unattended unit, including the communication and portable-shop installations, is about $1.5 million, or $250 per bhp on the basis of an expected annual average output of 6000 bhp. This is one sixth the investment per horsepower of a conventional community-type station in Saudi Arabia.

Turbine Van

Fig. 3 shows a simplified plan view of the turbine van. The gas turbine is a two-shaft simple-cycle unit, rated at 5000-hp shaft output at 110 F and 2600-ft altitude, and it burns crude oil taken from the pipeline. An aqueous solution of a corrosion-reducing additive, magnesium sulfate, is blended into the crude at the turbine. The crude oil contains about 10 ppm of vanadium and requires an addition of 0.03 per cent by weight of hydrous magnesium sulfate to minimize corrosion of the turbine blades. The additive system is contained within the turbine and control vans, and is automatically co-ordinated with the fuel requirements.

The turbine is started by a 200-hp diesel engine with torque converter drive. The engine is coupled to the gas turbine through a jaw-type clutch which automatically disengages when the turbine reaches self-sustaining speed.

The main crude-oil pump is driven directly at gas-turbine speed (5000-6000 rpm). The pump was manufactured by Byron Jackson Pumps, Inc., and is an extremely compact unit, with an over-all length of 5 ft 1 in., max width of 4 ft, max height of 4 ft, and weight of 4650 lb. The pump has the unique features of weighing less than 0.8 lb per bhp and delivering more than 600 psi differential with a single-stage impeller.

The turbine, in addition to driving the main crude-pump from the load turbine shaft, also drives a 125-kva generator from the compressor shaft. This generator supplies electric power for the entire auxiliary pumping unit when the gas turbine is operating.

The temperature of the cooling water for the gas-turbine lube-oil system and critical parts of the turbine is automatically maintained by circulating the water through two fin-fan units. Air is circulated through these units by two fans driven by 20-hp a-c motors. During cool-down of the unit, an auxiliary 5 hp d-c fin-fan cooler is used.

Control Van

Fig. 4 shows a simplified plan view of the control-filter van. The section of the enclosure containing the inlet air filter is open on top to admit air to pass through the filter for the gas turbine and for ventilation of the turbine and control rooms.

Mounted in the control room is the auxiliary panel which contains the electrical switchgear, motor starters, and control relays. Also mounted in this room are the turbine control panel, process control panel, and remote supervisory control panel, as well as the voltage regulator and battery chargers. Located between the battery chargers and voltage regulator is a 10-kva inverter used to supply constant frequency a-c power to some of the instruments, and to supply the basic power for the communication system.

Shop Van

The portable shop van is divided into two sections. One is a shop and parts-storage area equipped with power tools. The other is a personnel locker-room area, equipped with an electric kitchen and a washroom for use by maintenance personnel.

Radio Van

The radio van contains the vhf radio transmitters and receivers and a 30-kva auxiliary diesel-generator set. There are three 250-watt, 150-megacycle, fm transmitters in each van; two transmitters are for voice, tele-metering, and supervisory equipment, and the third is for mobile-equipment communication. The system employs scatter propagation and utilizes extremely high-gain antenna arrays mounted on 200-ft-high towers.

The auxiliary generator starts automatically when the gas turbine shuts down, and supplies power to the 208-volt bus to maintain lights, communication, essential services, and a charge on the 800-amp-hr battery bank. If the auxiliary diesel-generator set is temporarily out of service, the station battery, fully charged, is capable of supplying electric power for three complete start-ups and shutdowns of the gas turbine.

Control System

Fig. 5 shows the schematic routing of a control signal. In addition to the supervisory control, there are four telemeter functions, namely, ambient temperature, discharge pressure, and suction pressure at the unit, and discharge pressure set point which is the basic control function. Each of these four telemeter functions is continuous. The supervisory and telemetering information is simultaneously carried on two independent vhf circuits. Two circuits are provided to avoid an interruption of contact between the master station and the operating station in case one of the circuits fails. It also allows the use of diversity reception, which greatly improves the reliability of the system.

The basic functions required for controlling the turbine are the start and stop selector keys, the raise-and-lower set-point selector keys, and the selector keys con-
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connected to the voice-communication channel, which initiate contact so that a microphone in either the pump room or the turbine room of the operating unit can be heard at the master station.

Located on the master supervisory panel are three groups of lights indicating first, second, and third-order alarm groups. First-order alarms are serious enough that the turbine unit is tripped, and a trained technician should go to the station before restarting the unit. Other alarms may not cause tripping of the unit but, if they do, it is safe to restart the unit by remote control before the technician goes to the station to investigate.

Remote Control

For the start-up and operation of the unit by remote control, the operator at the master supervisory control first checks to make sure that the panel is clear of alarms and in remote-start position. He then depresses the "start" selector key. This action sends a signal to the turbine control panel which in turn sends a signal to the motor-starter panel to start the d-c motors of the auxiliary fans and pumps required for commencing operations. The main-line gate valves also open, pressurizing the main crude-oil pump.

After a five-minute interval required for purging the turbine van with the d-c purge fan, the starting diesel is automatically started, the clutch is engaged, and the turbine is accelerated to firing speed. After the turbine is fired, it is further accelerated to idling speed. During the acceleration, the breaker for the a-c-shaft-driven generator is closed; the a-c station motors are started in preset sequence and the d-c motors are shut down.

After that, a signal is sent back to the master control panel, indicating that the starting sequence has been completed. The entire sequence of operation is automatic once the operator depresses the start key.

The unit now is ready for adjustment of discharge-pressure set point. This set point is controlled by the operator, who depresses the raise-or-lower set-point selector keys as required. Once a set point has been established, the process control automatically maintains the required pump speed to maintain this discharge pressure.

Process Control

The process system basically compares a pneumatic pressure established by a transmitter (which converts a process pressure to a pneumatic pressure signal) with an established pneumatic pressure which is a function of the desired process pressure (set point). If there is a difference in these readings, an 'error' signal is sent to the turbine control to increase or decrease turbine speed accordingly.

In addition to the basic controls, there are overriding features which limit the rate of change of pressure and which limit the min suction and max discharge pressures to prevent damage to the pump or pipeline.

Permanent, Manned Units

The installation of two 5000-hp turbine pumping units at the permanent pump station at Turaif, Saudi Arabia, follows a more conventional pattern with the exception of a unique suction booster pump. When both turbines are in operation, an excess of hydraulic horsepower is available. Part of this horsepower is utilized to operate a hydraulic turbine-driven booster pump to provide a suction pressure of 60 to 90 psig for the main pumps. The hydraulic-driven pump was supplied as a package unit by Byron Jackson Pumps, Inc.

Operation and Maintenance

Up to Jan. 1, 1958, Aramco and Tapline had operated the gas-turbine pumping units for a total of approximately 10,000 hr. Most of these operations were carried out with personnel in attendance, many of whom were present only for possible emergencies or to record pertinent data from nonrecording instruments. One of the auxiliary pumping units had had several months of unattended operation, with an availability factor of better than 90 per cent. Another was successfully operated unattended after a trial run of only 80 hr.

Two of the auxiliary-pumping unit turbines have been disassembled at their regular locations, to make adjustments to main bearings and seals. A crane was moved to the turbine van and, after the removal of sections of the roof, parts of the turbine were removed and laid on a canvas on the ground outside, and protected by a canvas covering. Although dust storms occurred at frequent intervals, it was possible to do all the necessary work and make final adjustments during periods of clear weather. Such work can only be accomplished by a crew of men trained to work under adverse conditions.

Those parts which required machine-shop work were moved either by automotive equipment or by aircraft to and from the central machine shop at Turaif. This shop is equipped with a dynamic balancer, a test stand specifically designed for the turbine-control and auxiliary equipment, and the necessary machine-shop equipment to handle all parts.

Tapline plans to haul each turbine van to the central shop at Turaif for major overhaul. During these occasions the spare turbine van will be installed for temporary operation at the intermediate location.

Future Application

Preliminary operating experience indicates that the auxiliary pumping units will have a high degree of reliability and a relatively low operating cost, despite a fuel consumption per hp-hr approximately twice that of the originally installed diesel engines. Tapline is convinced that it has a well-designed pumping unit which can be operated successfully by remote control.

The feasibility of unattended gas-turbine pumping units definitely changes the economics of pump station spacing for large-diameter pipelines in the Middle East. Because of the lower investment per horsepower, the optimum spacing for unattended pumping units will be much closer for a given pipe size than for the older, extremely expensive stations of the community type.

Reference


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