Low-Noise Receivers: Microwave Maser Development

E. Wiebe
Communications Elements Research Section

This article summarizes the operational status of the closed-cycle refrigerators (CCRs) used to cool traveling-wave masers in the DSN. The improved CCRs have now replaced virtually all the old Model 210s. The reliability of the new system has lived up to all expectations. A continuing effort is made to simplify the system in order to further improve its reliability. The second part of this article describes a simple way of eliminating the oil pump which is used to cool and lubricate the compressor.

I. Performance of Closed-Cycle Refrigerators

In order to provide the Deep Space Instrumentation Facility with reliable operational equipment, the closed-cycle refrigerators (CCRs) developed at JPL (Ref. 1) have undergone extensive testing at JPL and at Goldstone for the past 6 years. Ten of these units were tested in R&D programs at JPL and at Deep Space Stations (DSSs) 13 and 14. A total of 333,000 h were logged on the running time meters located in the compressor assemblies. All units generally substantiate the specification that mechanical maintenance will not be required more than once a year.

An R&D X-band traveling-wave maser (TWM) was installed on the 64-m antenna at DSS 14 some 3 years ago and was used for many radio science experiments. It was also used to life test the refrigerator system, and no mechanical maintenance was performed during the test period. When it was recently removed from the antenna (because of DSS 14 scheduling), it had logged 23,000 h of trouble-free operation.

A charcoal trap in the helium gas supply line was serviced regularly, and proper start-up procedures were followed after each shut down, e.g., after electrical power outages.

Fourteen of the new CCRs have been installed as operational equipment in the DSN over the past 2 years, and these have logged over 100,000 h. Thus, a grand total of nearly half a million hours have been logged.

II. Oil-Lubricated Compressor

An ordinary air-conditioning compressor unit is used to supply the recirculating helium gas which is required in the CCR. The only modifications made in the unit are the addition of a small oil pump to the main drive shaft, and the rearrangement of the valves for cascade operation of the two cylinders, which are normally in parallel.

The oil pump is used to inject oil into the helium gas to cool the compressor, as well as to prevent blow-by, and to provide upper cylinder lubrication. Filters easily separate the oil from the gas, and clean helium gas is supplied to the CCR. Occasionally, the positive-displacement, gear-type oil pump has failed and caused some worry. In a continuing effort to simplify and improve reliability in the system, a scheme has been developed for eliminating the oil pump. Extensive testing is now underway to prove the practicality of the method.

Figure 1 shows a simplified schematic of the gas and oil flows in a system which uses an oil pump. The oil pump takes oil at crankcase pressure p_2 and delivers oil at p_3 ($p_3 - p_2 \approx 310\,\mathrm{kN/m^2}$) to the metering block A and heat exchanger 1; the bulk of the oil is returned to the crankcase and helps to cool the compressor. However, a small portion of the oil is fed through metering blocks A and B back to the first- and second-stage intake ports. It is noted that the second-stage intake pressure is the same as the crankcase pressure p_2. Thus, although oil flow can be maintained to the first-stage intake at p_1 without the oil pump, an oil pump is required to inject oil into the second stage. The oil separator eventually supplies most of the oil required for the second stage. However, it is incumbent on the system to be self-priming.

Figure 2 shows one simple way in which the oil pump may be eliminated. Oil from the crankcase is cooled by heat exchanger 1 and injected into the first stage of the compressor. The discharge from the first stage is cooled by heat exchanger 2 and returned to the crankcase via a relief valve V, which is set to approximately 172 $\mathrm{kN/m^2}$. Thus, oil at $p_2 + 172\,\mathrm{kN/m^2}$ is now available and may be injected into the second-stage intake port.

The additional work done by the first stage of the compressor is negligible, since the second stage performs most of the operation. However, there is a small increase in compressor temperature, since no cooling oil is available. Table 1 shows a typical set of temperatures for two systems operating side by side in otherwise identical operating conditions. The important parameter is the second-stage output temperature, which should be kept below 100°C to prevent decomposition of the oil.

Figure 3 shows the relief valve and tee which comprise the modification. The oil pump end plate is also modified by removal of the pump and substitution of a simple thrust bearing. Figure 4 shows an end view of the modified compressor assembly.

Reference

1. Higa, W. H., and Wiebe, E., "A Simplified Approach to Heat Exchanger Construction for Cryogenic Refrigerators," *Cryogenic Technology*, March/April 1967.

Table 1. Typical operating temperatures

	First-stage exhaust temperature, °C	Second-stage exhaust temperature, °C	Compressor housing temperature, °C
Compressor without oil pump	67	82	78
Compressor with oil pump	94	82	57

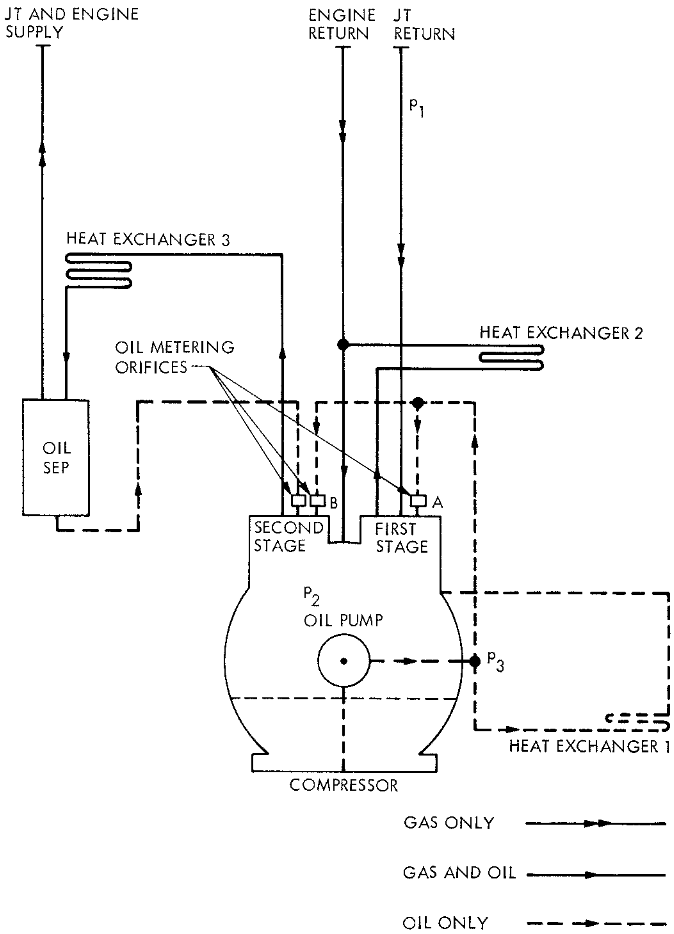

Fig. 1. Gas and oil in compressor assembly with oil pump

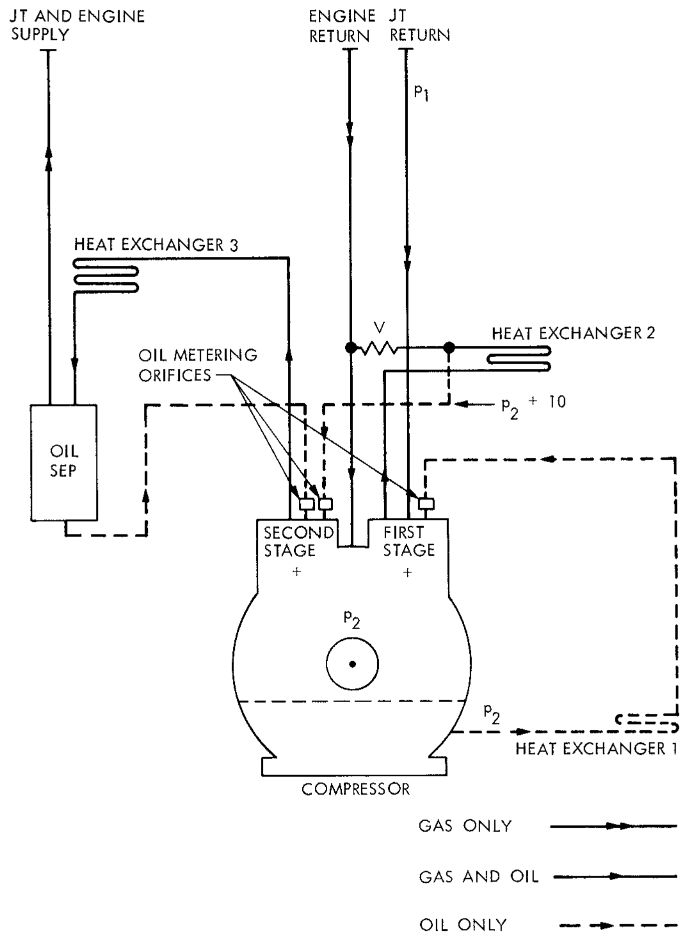

Fig. 2. Gas and oil flows in system without oil pump

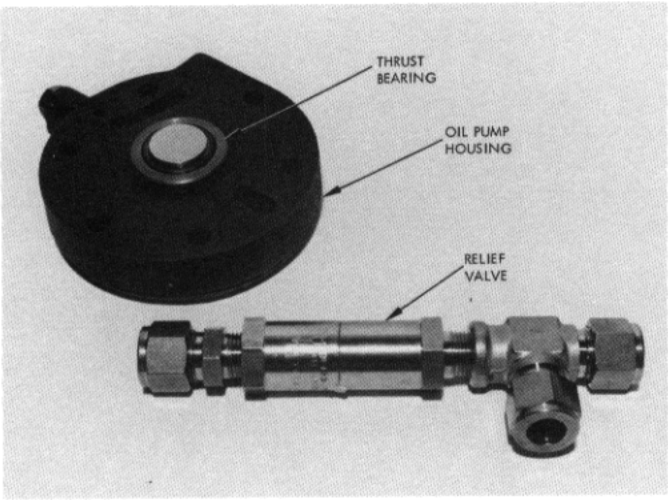

Fig. 3. Components required for modifications in compressor

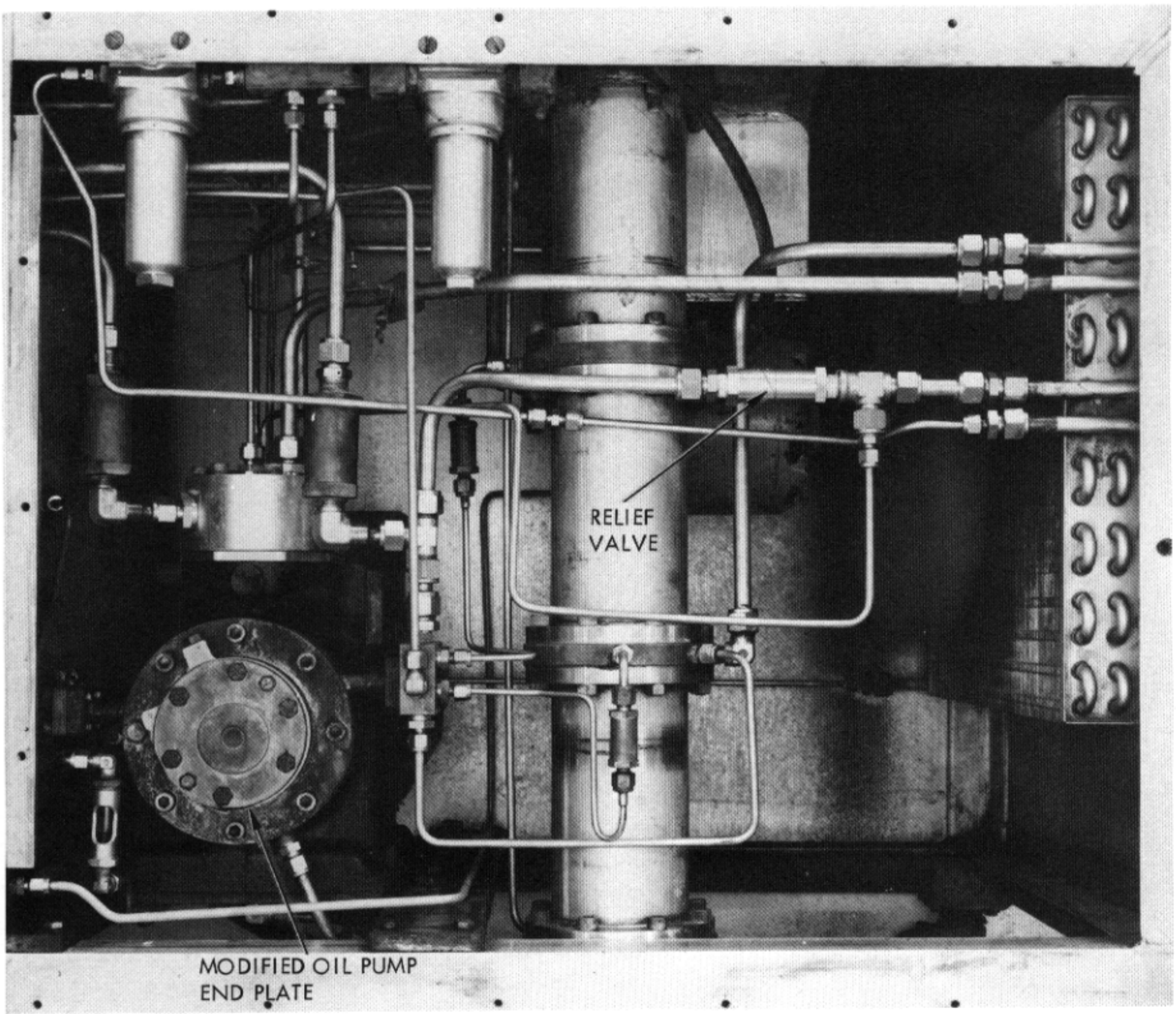

Fig. 4. End view of compressor with modifications installed