# Flexible Heat Pipes for CCD Cooling on the Advanced Camera for Surveys

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## ABSTRACT

The Advanced Camera for Surveys (ACS) is an instrument containing two charged-coupled device (CCD) cameras and a multi-anode multi-channel array (MAMA) detector being built by Ball Aerospace and Technologies Corporation for NASA's Goddard Space Flight Center. The instrument is scheduled to be installed in the Hubble Space Telescope during a space shuttle mission in December of 1999. The CCD detectors need to operate at a temperature below -80°C in order to avoid unacceptable dark current. This cooling is achieved with thermo-electric coolers (TEC) mounted in evacuated assemblies that contain the detectors. Heat that is generated by the TECs must be dissipated to space. Since the CCD assemblies are centrally located within the instrument enclosure, a method must be provided for transferring this heat to a heat rejection surface. Heat pipes have been selected for this purpose since they are frequently used in space applications for passively transferring heat from sources to remotely located radiating panels. The alignment of the CCDs is critical, however, so the loads induced into the detectors and the optical bench containing the sensor assemblies through heat pipes must be minimized. Consequently, the CCD heat pipes have been designed with a flexible section to minimize either thermally generated or launch induced structural loads. Structural and thermal testing has shown that these heat pipes will allow the ACS detectors to attain their operating temperature while meeting alignment stability requirements. This paper presents the design of and test results from the ACS flexible heat pipes.

Keywords: heat pipes, CCD cooling, heat transfer

## 1. NEED FOR HEAT PIPES TO AID IN COOLING ACS DETECTORS

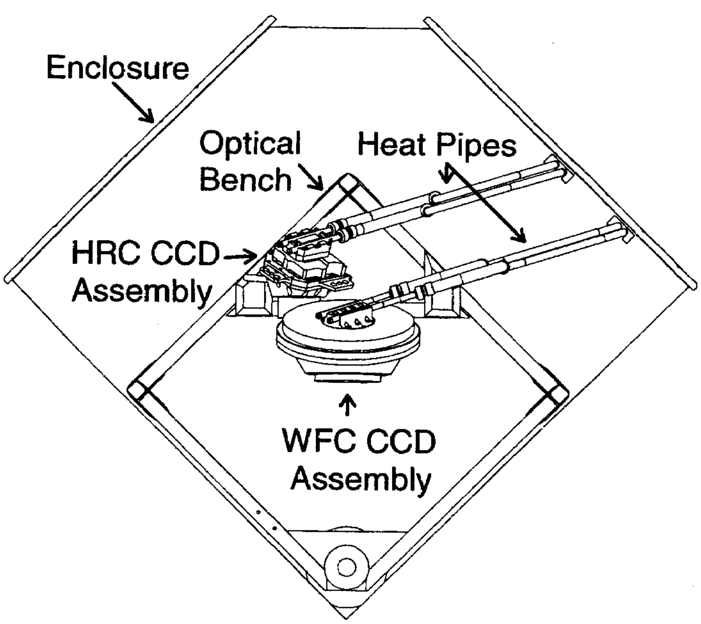


Figure 1. Location of CCDs Within ACS Enclosure

Thermo-electric coolers can provide the necessary cooling to the High Resolution Channel (HRC) and the Wide Field Channel (WFC) CCD detectors[1] to achieve a nominal dark rate noise of less than 50 e/pixel/hr estimated at an array temperature of -80°C. This performance can only be achieved, however, if the heat generated on the warm side of the TECs, as much as 30 W, is transferred to the cold environment of space. Figures 1 and 2 show layouts of the ACS instrument enclosure and optical bench. Most of the instrument mechanisms have been omitted to show the locations of the CCD assemblies within these structures and the routing of the flexible heat pipes. The TEC generated heat must be transferred from the assemblies to a radiator on the outer surface of the instrument. Since the ACS enclosure is contained within the HST aft shroud, the efficiency of a dedicated radiative surface on the instrument external surface is relatively poor. The location of the detectors within the instrument and the low thermal efficiency of the instrument configuration dictate the need for a high thermal conductance conduit. The clear choice for this type of application is heat pipes.



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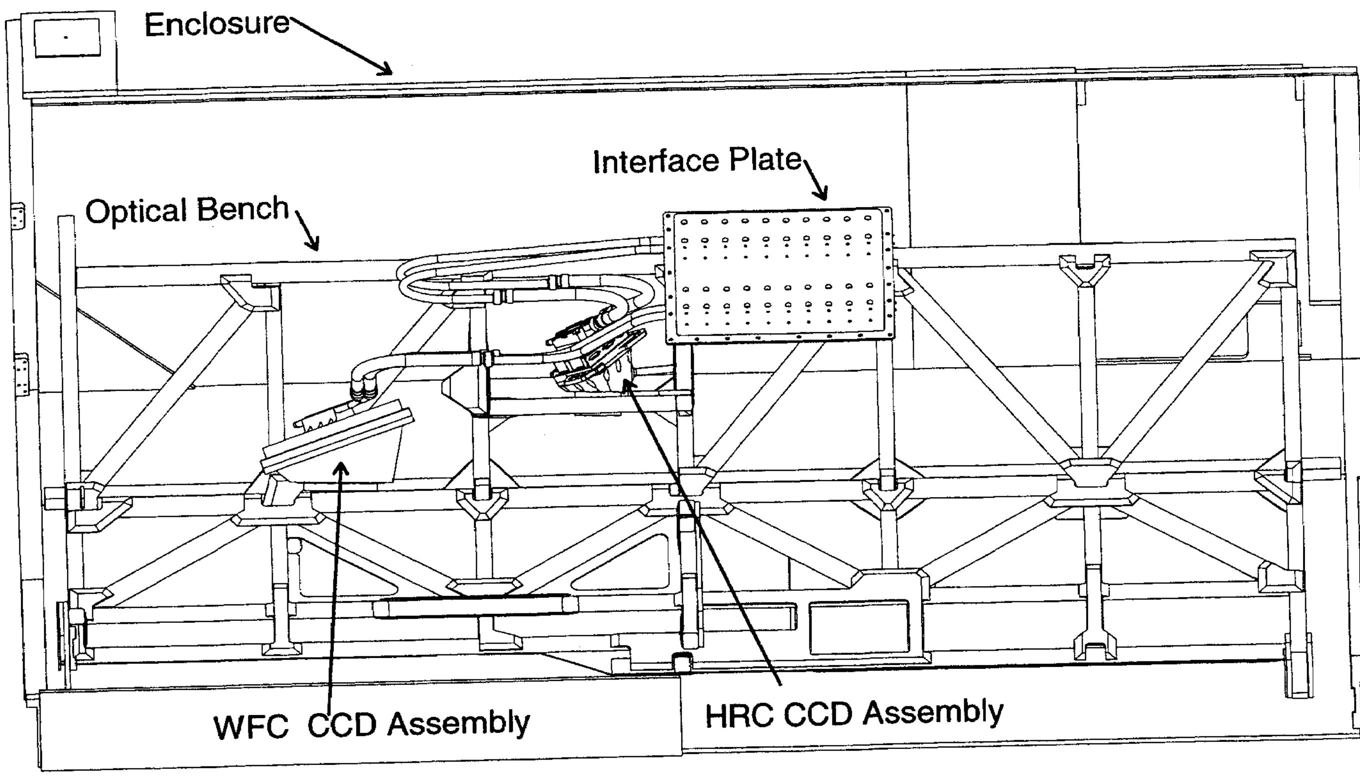


Figure 2. Heat Pipe Locations Within ACS

## 2. GENERAL DESCRIPTION OF HEAT PIPES

Heat pipes utilize the latent heat of vaporization of a contained working fluid to passively transfer heat from hotter to colder regions of the pipe. A wicking structure within the pipe generates capillary forces that draw liquid into the hotter regions where vapor is generated. The vapor is then channeled to the colder regions of the pipe where it condenses. Until the pressure drop within the heat pipe reaches the capillary limit of its wicking structure, performance is nearly independent of length. Heat pipes are best suited for space applications due to the absence of gravitational forces that otherwise work against the capillary forces if the pipe has any vertical component. In fact, heat pipes have been used on numerous spacecraft including other locations within the HST.[2] Heat pipes can also be configured to match each specific application.

## 3. MISSION CRITICAL POINTING REQUIREMENT

Besides heat transport capability, the other ACS performance requirement that has determined the design of the CCD heat pipes, is pointing accuracy. Though impossible to measure during ground testing, the image drift must be less than 10 milliarcseconds peak-to-peak over two orbits. In addition, jitter introduced by the instrument itself can cause an error no greater that 3 milliarcseconds over any 21 minute interval. The optical bench that contains the two CCD detector assemblies is kinematically mounted within the instrument enclosure, and thermostatically controlled heaters on the bench surfaces maintain the detectors in a thermally stable environment. The intention of controlling the bench temperature is to prevent any motion of the enclosure due to changes in thermal environment from affecting the instrument alignment. The CCD heat pipes are hard mounted to the CCDs at one end and to the enclosure on the other. Thus, any relative motion between the bench and enclosure can be translated to the CCDs through the heat pipes, defeating the purpose of the mounting technique. Several methods have been used in the past for adding compliance at heat pipe interfaces, including s-links[3] and copper braids.[4] With the small CCD interface areas, however, these couplings would result in an interface conductance on the order of 0.5 W/C. This conductance is an order of magnitude less than that without the compliance coupling and would thus severely limit the capability of the CCD cooling system.

Because of these constraints, a rarely used heat pipe design with a flexible section was selected for this application. In order to show this type of heat pipe would meet the performance requirements, two sets of tests were conducted. The first was a thermal performance test to show the pipe could transfer a sufficient amount of heat. The second was a loads test to verify that any loads translated into the optical bench through the heat pipes would result in displacements small enough to comply with the detector pointing accuracy requirements.

## 4. FLEXIBLE HEAT PIPE DESIGN

The flexible heat pipes contain ammonia as the working fluid and a rolled screen mesh wick held in position by additional screen mesh webbing. External tubing is 1.27 cm (0.5in.) OD, 316L stainless steel and the flex section is a standard Swagelok® twelve inch flexible metal hose composed of 316 and 321 stainless steel. Figures 3 and 4 show the HRC and WFC heat pipes and CCD interfaces respectively. These pipes are coplanar so that they may be tested on the ground for verification of proper wick operation. Two pipes connect to each CCD for one fault tolerance, and all four flex pipes connect to an aluminum interface plate located within an outboard panel of the instrument enclosure. Two standard, axially-grooved aluminum heat pipes thermally couple this interface plate to a face sheet radiator on the outside of the enclosure panel. The radiator components are shown in Figure 5.

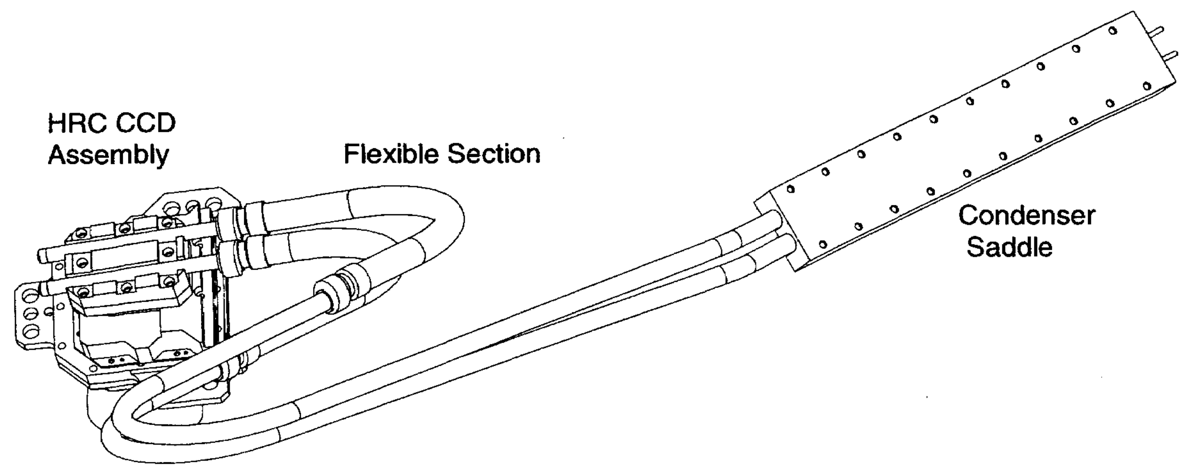


Figure 3. HRC Flexible Heat Pipe Assembly

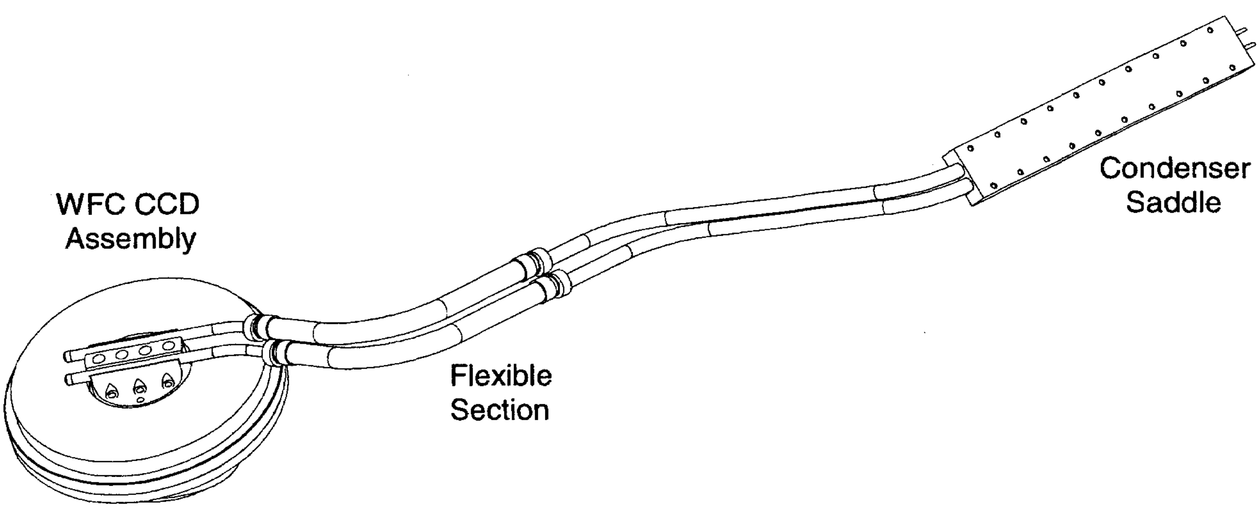


Figure 4. WFC Flexible Heat Pipe Assembly