COOLING IN LIQUID ROCKET:

What Is Meant By Cooling In Liquid Rocket?

The heat created during combustion in a rocket engine is contained within the exhaust gases. Most of this heat is expelled along with the gas that contains it; however, heat is transferred to the thrust chamber walls in quantities sufficient to require attention.

Thrust chamber designs are generally categorized or identified by the hot gas wall cooling method or the configuration of the coolant passages, where the coolant pressure inside may be as high as 500 atmospheres. The high combustion temperatures (2,500 to 3,600° K) and the high heat transfer rates (up to 16 kJ/cm^2-s) encountered in a combustion chamber present a formidable challenge to the designer. To meet this challenge, several chamber cooling techniques have been utilized successfully. Selection of the optimum cooling method for a thrust chamber depends on many considerations, such as type of propellant, chamber pressure, available coolant pressure, combustion chamber configuration, and combustion chamber material.

The primary objective of cooling in liquid rocket is to prevent the chamber and nozzle walls from becoming too hot, so they will no longer be able to withstand the imposed stresses, thus causing the chamber or nozzle wall to fail.

Methods Of Cooling In Liquid Rocket:

1. Regenerative Cooling
2. Dump Cooling
3. Film Cooling
4. Transpiration Cooling
5. Ablative Cooling
6. Radiation Cooling

Regenerative Cooling In Liquid Rocket:

Regenerative cooling is the most widely used method of cooling a thrust chamber and is accomplished by flowing high-velocity coolant over the back side of the chamber hot gas wall to convectively cool the hot gas liner. The coolant with the heat input from cooling the liner is then discharged into the injector and utilized as a propellant.

Earlier thrust chamber designs, had low chamber pressure, low heat flux and low coolant pressure requirements, which could be satisfied by a simplified "double wall chamber" design with regenerative and film cooling.

For subsequent rocket engine applications, however, chamber pressures were increased and the cooling requirements became more difficult to satisfy. It became necessary to design new coolant configurations that were more efficient structurally and had improved heat transfer characteristics.

This led to the design of “tubular wall” thrust chambers, by far the most widely used design approach for the vast majority of large rocket engine applications. These chamber designs have been successfully used and several other Air Force and NASA rocket engine applications. The primary advantage of the design is its light weight and the large experience base that has accrued. But as chamber pressures and hot gas wall heat fluxes have continued to increase (>100 atm), still more effective methods have been needed.

One solution has been “channel wall” thrust chambers, so named because the hot gas wall cooling is accomplished by flowing coolant through rectangular channels, which are machined or formed into a hot gas liner fabricated from a high-conductivity material, such as copper or a copper alloy.. Heat transfer and structural characteristics are excellent.

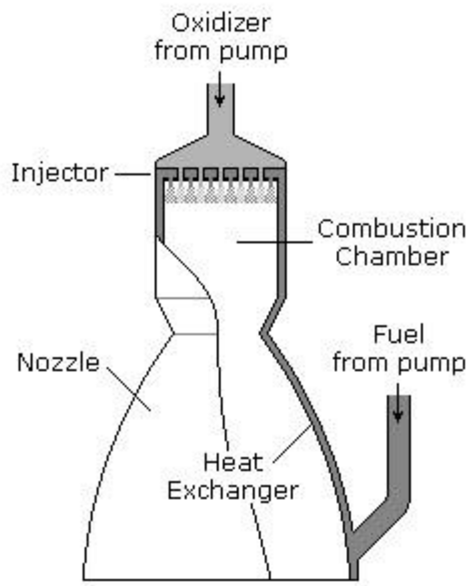
Basically, there are three domains in a regenerative cooled rocket engine.

1. Gas Domain (Combusted Gases) – Convection and Radiation heat transfer
2. Liquid Domain (Coolant) – Convection heat transfer
3. Solid Domain (Thrust chamber wall) – Conduction heat transfer

Heat transfer from the outer surface of thrust chamber to the environment can be neglected and the outer surface wall can be assumed as adiabatic.

In addition to the regenerative cooled designs mentioned above, other thrust chamber designs have been fabricated for rocket engines using dump cooling, film cooling, transpiration cooling, ablative liners and radiation cooling. Although regeneratively cooled combustion chambers have proven to be the best approach for cooling large liquid rocket engines, other methods of cooling have also been successfully used for cooling thrust chamber assemblies.

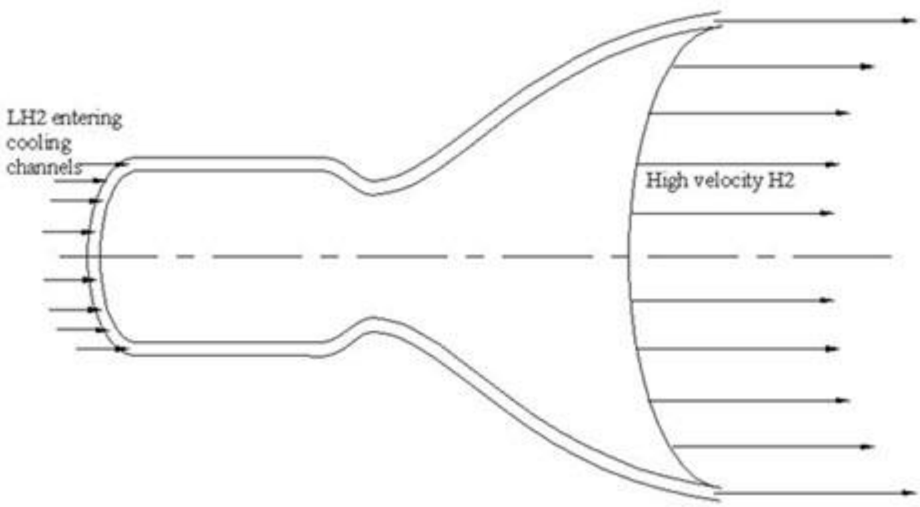
Regenerative Cooling In Liquid Propellant Rocket Engines



2. Dump Cooling In Liquid Rocket:

Dump cooling, which is similar to regenerative cooling because the coolant flows through small passages over the back side of the thrust chamber wall. The difference, however, is that after cooling the thrust chamber, the coolant is discharged overboard through openings at the aft end of the divergent nozzle. This method has limited application because of the performance loss resulting from dumping the coolant overboard. To date, dump cooling has not been used in an actual application.

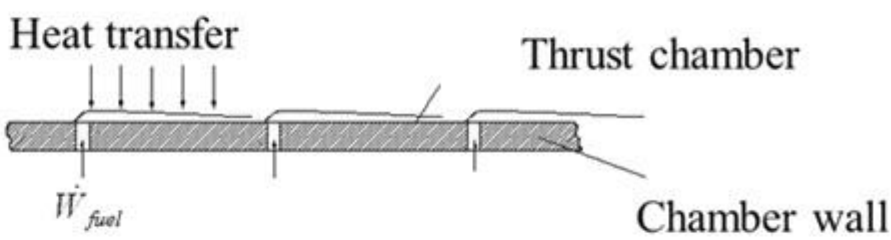
Dump Cooling In Liquid Propellant Rocket Engines



3. Film Cooling In Liquid Rocket:

Film cooling provides protection from excessive heat by introducing a thin film of coolant or propellant through orifices around the injector periphery or through manifolded orifices in the chamber wall near the injector or chamber throat region. This method is typically used in high heat flux regions and in combination with regenerative cooling.

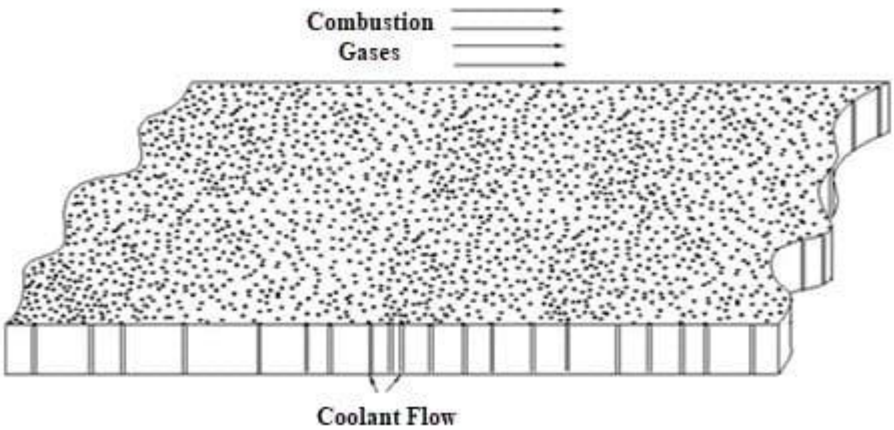
Film Cooling In Liquid Propellant Rocket Engines



4. <u>Transpiration Cooling In Liquid Rocket</u>:

Transpiration cooling provides coolant (either gaseous or liquid propellant) through a porous chamber wall at a rate sufficient to maintain the chamber hot gas wall to the desired temperature. The technique is really a special case of film cooling.

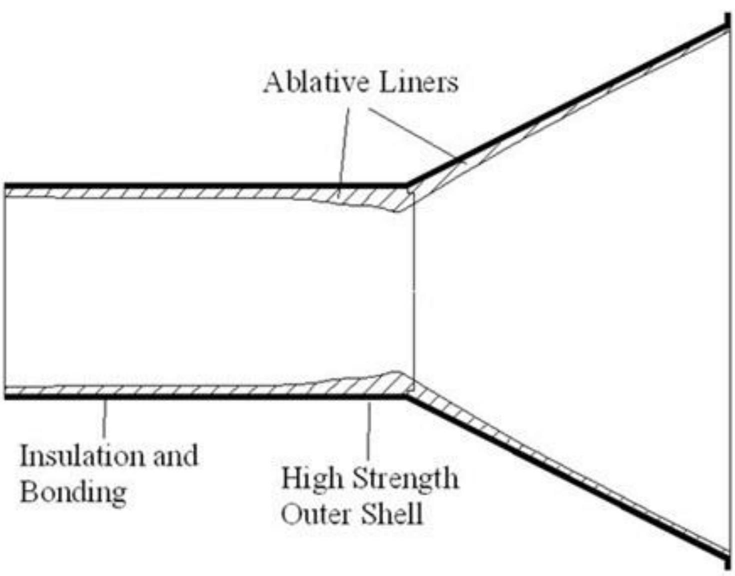
Transpiration Cooling In Liquid Propellant Rocket Engines



5. <u>Ablative Cooling In Liquid Rocket</u>:

With ablative cooling, combustion gas-side wall material is sacrificed by melting, vaporization and chemical changes to dissipate heat. As a result, relatively cool gases flow over the wall surface, thus lowering the boundary-layer temperature and assisting the cooling process.

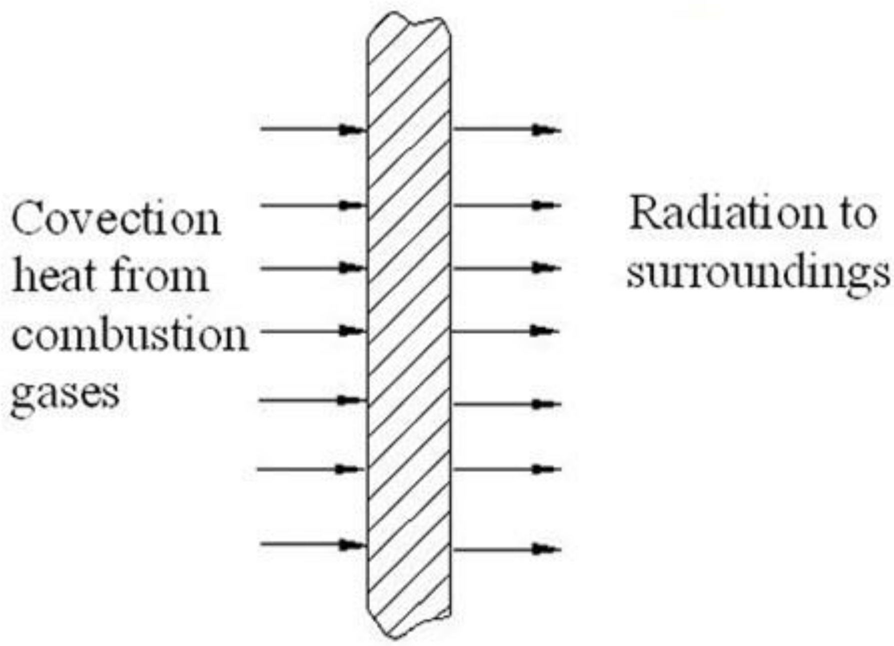
Ablative Cooling In Liquid Propellant Rocket Engines



6. Radiation Cooling In Liquid Rocket:

With radiation cooling, heat is radiated from the outer surface of the combustion chamber or nozzle extension wall. Radiation cooling is typically used for small thrust chambers with a high-temperature wall material (refractory) and in low-heat flux regions, such as a nozzle extension.

Radiation Cooling In Liquid Propellant Rocket Engines



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Unit 4 - History of Rocket Propulsion.

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