



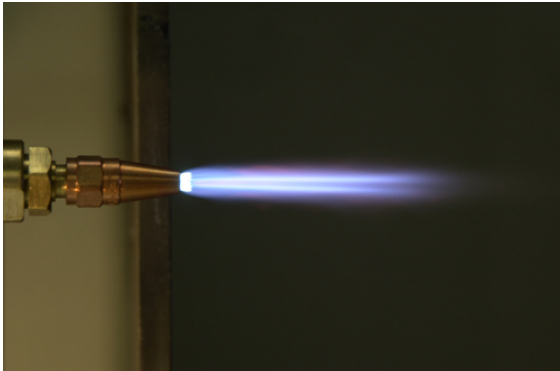
THE CUTTING FUEL FOR CUTTING COST

What is Chemtane 2 and How does it produce an increase in flame temperature?
This is a phenomenon we call "Secondary Combustion".

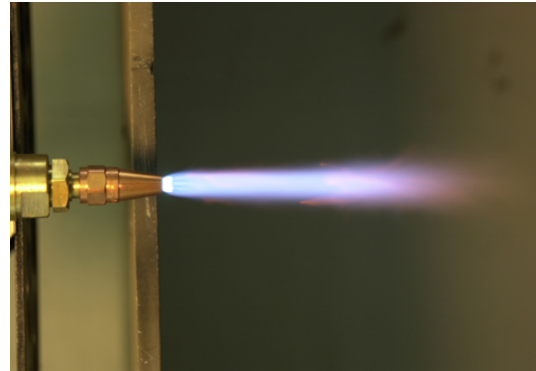
To answer this question we have analyzed the Flame Structure and the Action of Propane-Chemtane 2 with its unique additives:

Flame Structure

A premixed fuel and oxygen torch flame has a definite structure. There are four zones in the structure which are (1) the cool blue flame region (2) the inner cone (3) the outer cone and (4) the preheat zone outside of the flame. Chemtane 2 enhances a portion of the propane flame. This improves the cutting ability of the torch flame. Two photographs are provided labeled Pic3583 and Pic3589.



Chemtane 2 Pic. #3589



Chemtane 2 Pic.#3583

Pic3583 shows the stable premix flame and Pic3589 has excess oxygen added as used in cutting.

The Cool Blue Flame Zone

The first step in combustion in a premix flame is the combination of oxygen and the fuel gas. This produces oxygenated fuel molecules. Many of the combination reactions are endothermic (meaning they absorb heat) and thus the region is not at a high temperature. Some of the oxygenated molecules undergo combustion producing heat. Oxygenated molecules burn with a blue-white flame. The combustion of alcohol provides an example of the blue-white flame. Combustion is an exothermic reaction (that is, it produces heat). The cool blue zone thus has endothermic oxygenation reactions absorbing heat and exothermic combustion reactions producing heat. The net result is a flame that is cool by comparison with most flames and is blue-white in color. It is thus called the cool blue flame zone and it is located at the torch tip. It can be seen in both of the photographs as a small bright flame at the torch tip.

The Inner Cone Zone

The second step in combustion is the breakup of the primary products accompanied with additional oxidation. This is a fast free radical chain reaction. Almost all of the reactions are exothermic. The inner cone reaction zone produces much of the heat of combustion for the torch flame. The inner cone is visible in Pic3583 before excess oxygen is added. The highest temperature for most oxyfuel torch flames is at the tip of the inner cone. The inner cone is predominantly produced from the oxygen exclusively from the oxygen tank and is not diluted from the surrounding air with nitrogen and oxygen.

The Outer Cone Zone

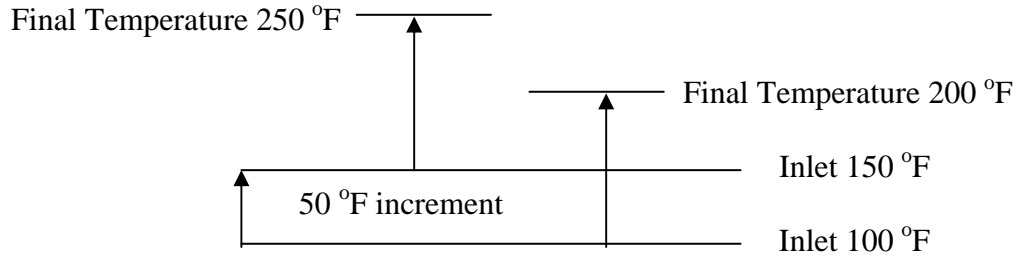
The third step in combustion is formation of the final combustion products from the primary products accompanied by additional oxidation. It is a free radical chain reaction with carbon dioxide and water as the reaction products. Intermediates are not predominantly formed in this stage. The reactions are exothermic. The outer cone reaction zone is diluted by the surrounding atmosphere. It thus has some reaction from atmospheric oxygen which is still a minor component compared to oxygen from the torch. There is a large admixture of inert nitrogen from the surrounding atmosphere. The outer cone is visible in Pic3583 before excess oxygen is added. The outer cone is responsible for much of the heat which is effective in preheat of the working piece.

Most of the time, engineers think in terms of the thermodynamic enthalpy of a fuel which predicts the amount of heat produced by combustion. Chemtane 2 does not add significantly to the thermodynamic enthalpic value of the fuel. How then can Chemtane 2 produce an increase in flame temperature?

Flame temperature can be calculated by knowing the initial temperatures of the oxygen and fuel, the heat of combustion (thermodynamic enthalpy) of the fuel and the combustion products along with their respective specific heat values at constant pressure (C_p). The mechanism of action whereby Chemtane 2 enhances the flame temperature is fundamentally a kinetic phenomenon not strictly a result of thermodynamics.

To understand the enhancement it is first necessary to understand the relationship of the initial temperature and the thermodynamic heating effect. Consider a given quantity of fuel which produces a given amount of heat and thus an increase in temperature.

Combustion of fuel
Increases temperature by 100 °F



In the example, the combustion of fuel increases the temperature by 100 °F no matter what the inlet temperature is. If the inlet temperature is raised by a 50 °F increment, then the final temperature is also raised by 50 °F.

If a small amount of additional propane (at the same inlet temperature is added) it will not increase the final temperature because the additional heat of combustion is insignificant. However, if a small amount of additional propane, at a temperature of 4000 °F higher than the inlet temperature is added, then the final temperature may be increased by several hundred degrees. This is not due to additional heat of combustion, but rather it is due to the additional heat input.

Now, this is significant to the situation with Chemtane 2 for kinetic reasons not strictly and only thermodynamic reasons. Say Chemtane 2 has a C₇ hydrocarbon and is mixed with a C₃ hydrocarbon (propane) which is then burned. In a given period of time the propane is burned. This is called the burn rate or velocity of combustion. The linear flow rate of fuel to the torch must be faster than the velocity of combustion. In this same period of time the C₇ hydrocarbon is partially burned giving a C₃ to C₄ hydrocarbon fragment which is heated to a high temperature like 4000 °F. The combustion process continues as the fragments travel away from the torch into the region of the inner and outer cone. Their combustion raises the flame temperature and does so at the outer edge of the inner cone. This is exactly where the heat is needed for cutting metal. It might be said that the "business end" of the cutting torch has been enhanced. The increased diameter of the hot zones allows smooth cuts and the increased length allows a greater working distance.

The phenomenon cannot be understood by looking at quantities and thermodynamic heats of combustion. A torch is not a closed thermodynamic system. When excess oxygen is added, as in actual cutting, the flame structure is changed. Pic3589 shows an enhanced bright region in the primary cone when the oxygen feed is increased. The hot zone is shaped like a cylinder and viewing it from the side, the top and bottom of the cylinder shaped zone is brighter. In this open thermodynamic system, the flame temperature cannot be modeled simply on a computer. The torch is turbulent flow and the mixing with air is variable. The enhancement cannot be predicted from knowledge of thermodynamic values, because they cannot account for kinetic phenomena. What is important is to evaluate fuel gas additives by experimental demonstration. *There is a variety of temperatures present at different zones in the flame structure of the torch. Chemtane 2 increases the temperature within the portion of the flame used for actual cutting.* Understanding the combustion kinetics as described provides good reason to put these materials to the test.