TABLE-continued

Summary of CFD Model Analysis at 750° C.

	Smooth Channel	Surface Feature Channel
O_2 conversion		
CFD	8.8%	11.2%
CFD Model Mass Balance	0.0%	0.0%
CFD Model Energy Balance	0.0%	0.0%

The performance improvement factor (at 750° C.) with surface feature=4.4×, thus stated that a catalyst would need to be 4.4× more active to achieve equal conversion performance if disposed on a flat or featureless channel.

Example

Exhaust Clean Up

[0269] This example simulates cleanup of the combustion exhaust (final 2500 ppm) in a simplified simulated combustion exhaust stream (containing only CH_4, O_2, and balance N_2).

Design Summary

[0270] The geometry included a 0.058 inch gap channel, 0.16 inch wide, and 3.5 inch long in a pellet type device, with a plate on either side of the 0.058 inch gap, which plates either had surface features recessed or had a flat surface. The surface feature pattern selected was SFG-1 on the two major opposing walls of the main channel, in a trans configuration, with 0.010 inch deep features each having a 0.015" span and a 0.015" feature spacing.

Fabrication Details

[0271] To minimize background activity the parts in the device had a chromia scale (grown via heat treatment of inconel 617, where the channel was heated to 1000 C for 4 hours in a dilute mixture of oxygen and nitrogen).

[0272] Platinum dispersed on fumed alumina was washcoated onto the flat and surface feature containing coupons after heat treating them to grow a chromia scale. The washcoat catalyst was a 50% Pt, 3% CaO on fumed alumina, loaded to ~10 mg/in^2. The blank coupons were flat and prepared with a chromia scale, but no catalyst.

Experimental Setup

[0273] The air and "fuel" (N_2+CH_4) were preheated separately in coiled tubing, then the air was injected immediately upstream of the device pellet. Since N_2 was substituted for all CO, H_2, CO_2, and H_2O in the simulated exhaust, the kinetic activity was expected to be different than if water were included in the feed. Flows were designed such that 2.05% O_2 would remain in the exhaust if all CH_4 were combusted. Temperature (750-950° C.) 2) N2 flow rate (7.383-3.184 SLPM)

Held constant: CH4 flow rate (0.0213 SLPM), O2 flow rate (1.035 SLPM), and apparatus

Results

[0274] There was a statistically significant difference measured in conversion of CH_4 between the flat and surface featured coupons (24% relative higher conversion at 750° C. and 7% relative higher conversion at 900° C.). CFD simulations confirmed that the initial data at 750-850° C. for the flat pellet were indeed largely mass transport limited and that an increase in catalyst activity of 4.4 times would be required to achieve the same relative increase in methane conversion as was obtained by the addition of surface features. Mixing of air and fuel immediately before entering the pellet greatly decreased the measured background activity even for temperatures as high as 950° C.

Example

Pressure Drop

An experimental study was conducted to determine the pressure drop in the channel with surface features and compare it to the pressure drop in the channel without surface features.

[0275] A device was made with SFG0 patterning on both major (opposing) walls of the main channel, in a cis-A orientation. Seven pressure locations were made between inlet and outlet to measure pressures at different locations in the channel. The channel dimensions were 0.16 inch by 0.020 inch by 6.985 inch length.

[0276] The surface features were in V shape with 45° angle between the arms of the surface features. The opening of surface features was 0.015 inch and were separated by 0.015 inch between features. The depth of each surface feature was 0.010 inch. The two arms of "V-shape" were connected by curve with radius of 0.008". The other ends of the feature legs (or arms) had a semi-circular shape.

[0277] Air was used as the fluid. The stand consisted of one mass flow controller flowing Air, 9 solenoid valves, and 2 differential pressure transducers (0-5 psid and 0-15 psid). The system was completely automated such that after the mass flow controller was calibrated for the various flow rates, and the tubes were attached, Labview would set the flow rate, open the solenoid valves associated with the 1st port, determine which dP transducer to use (either the 0-5 psid or the 0-15 psid), hold for steady state, record the value then move to the next port. The steady state was defined when there was less than 1% variation in the pressure.

[0278] The run plan was designed to test the effect of surface feature on pressure drop for different fluids and at different flow rates. The fluids chosen for testing were water and air. The flow rates were varied to obtain Reynolds numbers in both the laminar and transition regimes. Below is the run plan for the experimental testing.

	Run 1 For device without surface features					
Experiment No	Fluid	Surface-feature	Flow rate	Flow rate units	Mass flow rate (kg/s)	Reynolds number
ARSTH1	Air	No	4.88	SLPM	1.048E−04	2519
ARSTH2	Air	No	6.00	SLPM	1.289E−04	3097