

**The effect of grain growth of electrode material on power
output of alkali metal thermal electric converter**



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By

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I.D

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SESSION: 2013-2015

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RESEARCH COMPLETION CERTIFICATE

Certified that the research work contained in this thesis titled, "**The effect of grain growth of electrode material on power output of Alkali Metal Thermal Electric Converter**" has been carried out and completed by **Muhammad Talha Anwar, ID: 13002139023**. The quantum and the quality of the work contained in this thesis is adequate for the award of Degree of MS/M.Phil.

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DEDICATION

I dedicate this research work to my parents, brother, sister and teachers especially to my supervisor Prof. M. A. K. Lodhi. Without their guidance, understanding, support, and love, the completion of this research work would not have been possible.

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Author

Dua from Quran

God is the Most High and the True King. (Muhammad), do not be hasty in reading the Quran to the people before the revelation has been completed. "Say, My Lord, grant me more knowledge."

(sūrat tā hā, verse114)

ABSTRACT

The Alkali Metal Thermal Electric Converter (AMTEC) is one of the most desirable device for directly converting heat into electrical energy among the thermal convertors. Electrode and electrolyte, components of AMTEC play an impotent role in the degradation of power output. This research work is focused on the electrodes of the AMTEC. Power output can be controlled by improving electrodes of the AMTEC for the use of long time operation.

The effect of time of operation of AMTEC when operated continuously for 150,000 hours is studied on the degradation power output. The power output declines as, the time of operation increases. This is because of the electrode material. The grain size of the electrodes material increases with time of operation. The grain size increment reduces the power output.

We examine values of grain size by keeping time of operation the same but vary the parameter "a", the grain size increases with the increases of "a". The degradation of power output occurs 28 % after 150000-hour operation.

It is observed R_f remains almost constant for all time operation for smaller values of $a = 1.141 \times 10^9$ but for higher values of "a", R_f start increasing rapidly.

The parameter "a" has been usually treated as constant for all practical purposes. It is proportional to a product of M_0 and γ_s . The value of γ_s decreases as the

temperature increases, whereas M_0 increases as the temperature increases. As the mobility parameter "a" remains constant to some extent. However, when the temperature goes very high the parameter "a" may not remain constant as the proportionality of "a" to M_0 and γ_s is not of

the same order. At high temperatures one may out weight the other and thus "a" may not remain constant at advanced temperatures. This works through has been done at one temperature ≈ 1023 K but analyzed the effect of "a" on the grain size and thus on power output.

Power degrades as the grain size increases. For smaller values of parameter "a" grain size remains almost constant for all time of operation. But for higher values of "a" "grain size increases rapidly, no matter for how long the operation is supported. So the degradation of power depends upon the increase in grain size and for the larger values of parameter "a".

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10^7 81

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Nomenclature

Abbreviations

<i>AMTEC</i>	Alkali metal thermal electric converter
<i>ARPS</i>	Advance Radio Isotope Power System
<i>BASE</i>	Beta alumina solid electrolyte
<i>EM</i>	Electromagnetic Pump
<i>EMF</i>	Electromagnetic force
<i>MHD</i>	Magneto Hydro Dynamic
<i>PPF</i>	Pluto Fast Flyby
<i>PV</i>	Photovoltaic
<i>SNI</i>	Space Nuclear Initiative
<i>SNRP</i>	Space Nuclear Power Reactor
<i>TI</i>	Thermionic
<i>TPV</i>	Thermo Photo Voltaic

Symbols

a	Mobility parameter
B	Temperature independent exchange current $A K^{\frac{1}{2}}/Pa m^2$
B_0	Initial temperature exchange current
E_A	Activation energy 175.5kJ/mole
F	Faradays constant (96,485C/mole)
G	Geometric factor for pressure losses
J	Electrode current density (A/m^2)
J_a	Current density at anode
J_c	Current density at cathode
J_y^0	Exchange current density
M_0	Mobility constant
M	Mobility factor
M'	Molecular weight of sodium (23 g/mole)
n	Characteristic of electrode
P	Pressure of the sodium
P_a	Vapor pressure at anode/BASE surface
P_c	Pressure at cathode/BASE interface
P_{cond}	Pressure at condenser side
P_c^{oc}	Sodium vapor pressure at the cathode/BASE interface
P_e	Power output that is measured in Watts (W)
$P_{electric}$	Power output that is measured in Watts (W)
ΔP	Pressure difference

Q_{cold}	Hot side temperature of AMTEC
Q_{hot}	Cold side temperature of AMTEC
R	Radius of grains
R_g	Universal gas constant 8.314J/mole - K
R_0	Initial grain size
R_f	Final grain size
t	Time period (s)
T_B	Temperature of BASE
T	Hot side temperature of AMTEC
T_B	Temperature of BASE (K)
T_{min}	Minimum Temperature
T_{max}	Maximum Temperature
T_{cond}	Temperature at condenser side
v	Grains Velocity (ms^{-1})
V_0	Output voltage
V^{oc}	Open circuit voltage (V)

Greek Letters

γ_s	Individual surface energy of the grain boundary
γ_b	Average surface energy
η	Efficiency
ϕ	Angle between Individual Grain Boundaries
ξ^a, ξ^c	Charge exchange polarization at anode and cathode

Introduction

1.1. Energy Problem and Solutions

We, human beings have progressed a long way from the wandering hunter-gatherers of the ice age to urbanized human beings of today. Looking through the lens of history we find that each generation of human beings has faced new challenges but has also been provided with new opportunities. Our planet is an isolated system and therefore our problems are self-generated. Fossil fuels have powered our modern energy-thirst for nearly 2000 years. However, today, we are paying the cost of our irresponsible and blatant use of fossil fuels.