



# ESSO EASTERN INC.

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R. L. PRESTON  
PROJECT EXECUTIVE

NATUNA PROJECT

February 3, 1981

Mr. G. A. Northington  
Exxon Research & Engineering Co.  
Florham Park, N.J.

ETR 81-1

CO<sub>2</sub> Emissions  
Natuna Gas Project

FILE: 68-4-1-5

Dear Gene:

Sometime ago you passed to me a rough calculation you had made regarding the potential level of total emissions of CO<sub>2</sub> from producing Natuna Gas and subsequent burning of the LNG manufactured from the gas relative to what would be emitted if Natuna gas were not produced and coal was burned as a replacement for the LNG. Your calculation (attached) indicates that the total CO<sub>2</sub> emissions from producing Natuna gas and burning the LNG would be no higher than what would be emitted by burning an amount of coal equivalent in heating value to the LNG. This result is reflective of the fact that: (1) the CO<sub>2</sub> emitted per unit of heating value is higher for coal than for LNG because of the higher carbon content of coal (or conversely the lower hydrogen content), and (2) producing LNG at Natuna will result in the release of a significant amount of CO<sub>2</sub> because of the high CO<sub>2</sub> content of the raw gas.

I have made a brief, independent analysis of the relative release of CO<sub>2</sub>. A copy of the calculation is attached. In the calculations, I have attempted to be somewhat more rigorous, firstly, in simulating the chemical, ash and moisture content and the heating value of coal likely to be burned in Japan (the properties used reflect a composite of some typical Australian coals) and, secondly, in reflecting, in a gross sense, the relative heat release from burning coal or LNG in a commercial boiler.

The calculations indicate that the total release of CO<sub>2</sub> from producing Natuna gas and burning of the LNG manufactured from the gas would be almost twice that emitted by burning an equivalent amount of coal. The CO<sub>2</sub> released from burning coal is calculated to be almost twice that from burning LNG (this result is consistent with the generalized data presented in Table 1 of S. Knisely's memorandum on "Controlling the CO<sub>2</sub> Concentration in the Atmosphere," issued by Exxon Engineering's Petroleum Department, dated October 16, 1979); but producing this volume of LNG at Natuna releases nearly 40% more CO<sub>2</sub> than is released from burning coal.

February 3, 1981

Based on these calculations, the CO<sub>2</sub> content of the raw gas at Natuna would have to be around 50% for the total CO<sub>2</sub> emissions to be equivalent.

It appears to me that there are two major reasons for the differing results of the two calculations. First, you assumed coal to be 100% carbon, but the heating value you used for coal (10,750 BTU/Lb) represents an "as-received" coal with some level of moisture and ash. The heating value of pure carbon is 14,100 BTU/Lb. This resulted in an overstatement of the amount of coal required, and thus the amount of CO<sub>2</sub> emitted, for a given level of heat release. Second, you used a CO<sub>2</sub> content of raw Natuna gas of 63%, whereas the nominal level we have been using for planning purposes is 71.8%. Adjusting your calculations for these two factors would bring the results of both calculations into close agreement.

Both of these calculations are, of course, very rough approximations. To get a more accurate evaluation one would need to determine more precisely the relative heat liberated by both fuels in a commercial boiler, which would, of course, involve a determination of relative stack temperatures, excess air, etc.; and the energy consumed in the producing (or mining), manufacturing, shipping and terminalling of each fuel. It is also likely that the relative release of CO<sub>2</sub> could vary significantly, depending on the specific coal considered. While the boiler efficiency would probably favor LNG, I would guess that coal would probably have the advantage in terms of the overall energy consumed in getting the fuels out of the ground and to the market. This would seem to be particularly true in the case of Natuna, where fuel requirements will be higher than in conventional LNG projects because of the need to either vent or reinject the CO<sub>2</sub> recovered from the raw gas. For example, including transportation and receiving losses, as well as fuel requirements for producing and liquefaction, around 1.6 times as much hydrocarbon will need to be produced as will finally be received at the boiler burner. While the energy requirements for coal mining, etc. are undoubtedly substantial also, I doubt they will be this high.

You may want to have one of your engineers look over these calculations to see if any additional light can be shed on this subject. However, I doubt that any extensive additional work is justified.

Very truly yours,



G. R. Gervasi

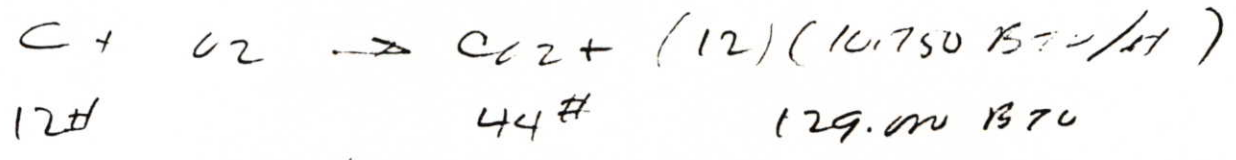
GRG:jdj/mkf  
Attachments

cc: R. L. Preston  
G. J. Lookabaugh

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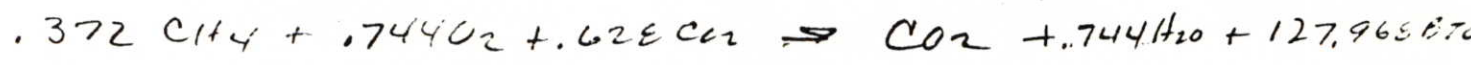
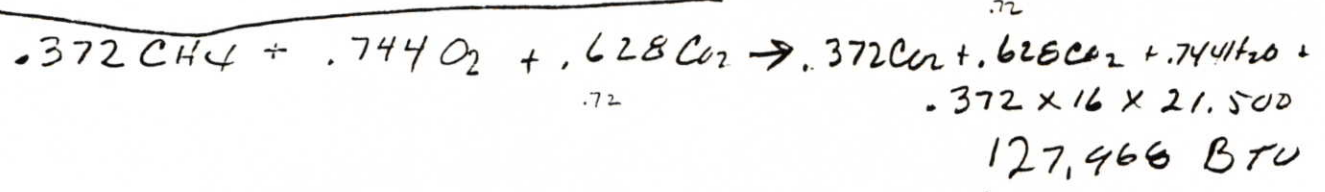
MR JOHN WOODWARD - What do you think of this  
Case  
Number

COAL BURNED IN JAPAN



$$\frac{1,000,000}{129,000} \times 12 \text{ 93\# coal} \div \frac{1,000,000}{129,000} \times 44 \text{ 600 344\# CO}_2 \text{ AND } 1,000,000 \text{ BTU}$$

METHANE BURNED IN JAPAN (CO2 IN GAS VENTED ex. Nat. gas)



$$\frac{1,000,000}{127,966} \times 7.81 \text{ 2.9 CH}_4 + 5.61 O_2 + 4.9 CO_2 \rightarrow 7.81 CO_2 + 5.61 H_2O + 1,000,000 \text{ BTU}$$

46.5#                      5.62                      343.8#

CO2 Emission

EXCLUDING ANY CO2 Produced to liquefy coal to separate the CO2 from the CH4 or NATURAL GAS  
IF THE CO2 WERE 37% CO2  
63% CO2

The CO2 emission from Natural Gas is no more than the CO2 emitted from coal to produce the same energy in Japan.  
KEEP IN MIND THAT IT TAKES ENERGY TO LIQUEFY NATURAL GAS TO SEPARATE THE CO2 FROM THE WEST VIRGINIA GAS TO JAPAN

SUMMARY OF G.R. GERVASI  
CALCULATIONS

CO <sub>2</sub> emitted from burning coal equivalent to 1M BTU heat release, Lbs	<u>253</u>
CO <sub>2</sub> emitted from burning LNG equivalent to 1M BTU heat release, Lbs.	128
CO <sub>2</sub> emitted in producing raw gas equivalent to that required to manufacture sufficient LNG for 1M BTU heat release, Lbs	345 —
Total CO <sub>2</sub> emitted for LNG case	<u>473</u>

COAL BASIS

MOISTURE	8% wt.
ASH	12 "
CARBON	82 wt (ash/moist. free)
HYDROGEN	6
OXYGEN	8
NITROGEN	3
SULFUR	1
	<u>100</u>

LNG BASIS

C <sub>1</sub>	98.1 mol%
C <sub>2</sub>	0.1 "
N <sub>2</sub>	1.8 "
HHV	23,135 BTU/LB
LLV	20,850 BTU/LB
Gas as produced:	
	71.8 % CO <sub>2</sub>
	27 % Hydrocarbon

SIMPLIFIED APPROACH

## ASSUME

- SAME EXCESS AIR FOR BOTH FUELS
- " STACK TEMP. " " "

1. GROSS HEATING VALUE OF COAL

## BY DULONG FORMULA

$$\text{BTU/LB} = 155.44C + 621(H - \frac{1}{8}O) + 40.5S$$

$$= 155.44 \times 82 + 621 \left( 6 - \frac{8}{8} \right) + 40.5 \times 1 = 13,060 \text{ moisture/ash free-basis}$$

$$\text{as received basis} = 13,060 \times \frac{100 - 12 - 8}{100} = 10,448 \text{ BTU/LB.}$$

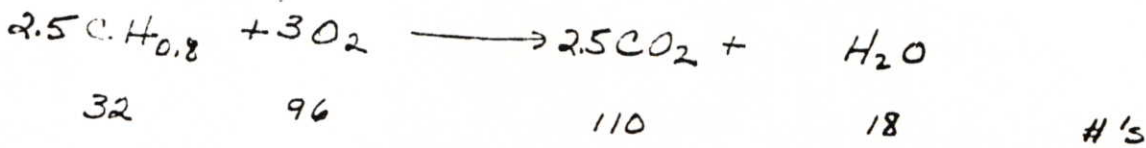
2. NET HEATING VALUE OF COAL

• ADJUST FOR H <sub>2</sub> comb. - HHV	61,070
LLV	<u>51,600</u>
	9,470 BTU/LB H <sub>2</sub>

$$0.06 \times 0.8 \times 9470 = 454 \text{ BTU/LB As Rec'd COAL} = \text{ADJ. TO COAL HHV}$$

$$\therefore \text{LLV} = 10,448 - 454 = 9994 \text{ BTU/LB}$$

### COAL COMBUSTION



$$\text{C.H}_{0.8} : \quad \% \text{ H}_2 = \frac{0.8}{12.8} = 6\%$$

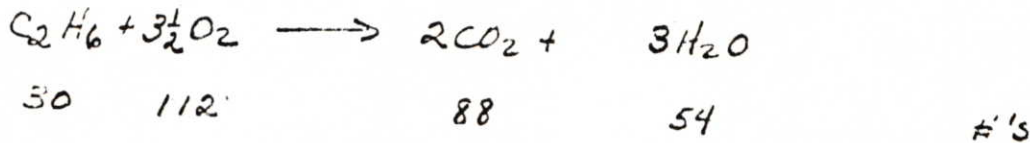
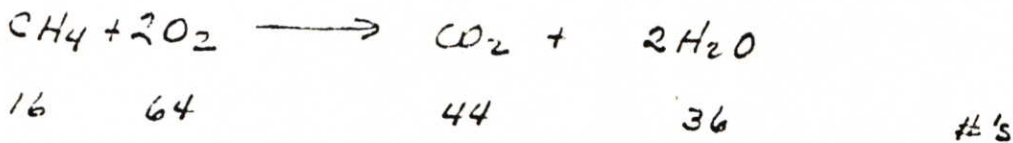
IF BURN 1# AS REC'D COAL LIBERATE 9555 BTU

TO GET  $1 \times 10^6$  BTU'S MUST BURN  $1 \times 10^6 \div 9555 = 104.7$  #'s AS REC'D COAL

IF BURN 104.7 #'s AS REC'D COAL; BURN  $104.7 \times 0.80 \times 0.88 = 73.7$  # OF

WHEN BURN 73.7# C.H<sub>0.8</sub> YIELD  $\frac{73.7}{32} \times 110 = \underline{253.3}$  #'s CO<sub>2</sub> C.H<sub>0.8</sub>

### N.G. COMBUSTION



	<u>MOL FRACT</u>	<u>WT FRACT</u>
C <sub>1</sub>	$0.9805 \times 16 = 15.727$	0.966
C <sub>2</sub>	$0.0014 \times 30 = 0.042$	0.003
N <sub>2</sub>	$\frac{0.0181}{1.0} \times 28 = 0.509$	0.031
	1.0	16.278

IF BURN 1# NG LIBERATE 20,850 BTU (LHV)

TO GET  $1 \times 10^6$  BTU MUST BURN  $1 \times 10^6 \div 20,850 = 47.96$  # of NG

IF BURN 47.96 # of NG; BURN  $47.96 \times 0.966 = 46.33$  #'s CH<sub>4</sub>  
 $\frac{47.96}{4} \times 0.003 = 0.14$  #'s C<sub>2</sub>H<sub>6</sub>

WHEN BURN:

46.33 # CH<sub>4</sub> YIELD  $\frac{46.33}{16} \times 44 = 127.4$  # CO<sub>2</sub>

0.14 # C<sub>2</sub>H<sub>6</sub> YIELD  $\frac{0.14}{30} \times 88 = 0.4$  # CO<sub>2</sub>

Total 127.8 # CO<sub>2</sub>

CO<sub>2</sub> RELEASED IN PRODUCTION OF N.G.

ASSUME GAS COMP. = 71.8 % CO<sub>2</sub>  
27 % N.G.

TO PRODUCE 47.96 #S OF N.G. OR  $\frac{47.96}{16.278} = 2.95$  MOLDS OF N.G.

REQUIRES PRODUCTION OF  $\frac{2.95}{0.27} \times 0.718 = 7.84$  MOLDS OF CO<sub>2</sub>  
OR 345 #S OF CO<sub>2</sub>

TOTAL CO<sub>2</sub> EMITTED TO ATMOS

COAL COMBUSTION =		253.3 # CO <sub>2</sub>
N.G. COMBUSTION	127.8	
N.G. PRODUCTION	<u>345</u>	
TOTAL		<u>472.8 # CO<sub>2</sub></u>

FOR BREAKEVEN ONLY  $253.3 - 127.8 = 125.5$  #S OR 2.85 MOLDS CO<sub>2</sub>  
BE RELEASED DURING  
PRODUCTION

∴ REQ'D COMP. AT B.E. :  $\frac{2.85 \text{ MOLDS CO}_2}{2.95 \text{ MOLDS N.G.}} ; \frac{2.85}{5.80} = \underline{\underline{49}} \text{ \% CO}_2$   
5.80

- NO ADJUSTMENT FOR C SINCE PRODUCES NO H<sub>2</sub>O.

### 3. HEAT LOSSES SPECIFIC TO COAL

- MOISTURE IN COAL

H@ 60°F vapor	1088
H@ 60°F liq.	<u>28</u>
AH	1060

ADJUSTMENT TO COAL (LLV) =  
 $1060 \times 0.08 = 85 \text{ BTU/LB AS REC'D COAL}$

- ASH IN COAL

- ASSUME:
- SP. HT CINDER = 0.25 BTU/LB-°F
  - CINDER CONTAINS 20% COMBUSTIBLE
  - CINDER LEAVES BOILER AT 1500°F

CINDER FORMED =  $\frac{0.12}{1-0.2} = 0.15 \text{ LB}$

COMBUSTIBLE LEFT IN CINDER =  $0.15 \times 0.2 = 0.03 \text{ LB}$

Ht LOSS:

SENSIBLE HT =  $0.15 \times (1500-60) \times 0.25 = 54 \text{ BTU/LB COAL}$

HT OF COMBUSTION =  $0.03 \times 9994 = 300$

TOTAL	<u>354</u>
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### 4. HEAT AVAILABLE FROM COAL

AS RECEIVED COAL:  $9994 - 85 - 354 = 9555 \text{ BTU/LB}$

CH WT BASIS =  $\frac{9555}{0.8 \times 0.87} = 13572 \text{ BTU/LB}$



