Palm Oil Products and Wastes as Alternative Energy Sources*

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ABSTRACT

This paper reviews on-going studies in Malaysia on the possibilities of utilizing palm oil products and wastes as alternative energy sources. The palm oil industry, being one of the biggest agricultural industries in Malaysia, produces palm oil from the shell and palm kernel oil from the kernel as the main products. Besides, liquid waste in the form of palm oil mill effluent (POME) and solid wastes such as shells, bunches and fibres are produced.

Work carried out on the direct use of Refined Bleached and Deodorised (RBD) olein (marketed as cooking oil) in a diesel engine has shown some positive results. However, further study has to be carried out to improve the engine performance and fuel utilization. Work is also being carried out on the possibility of processing palm oil into diesel fuel as an alternative to petroleum derived diesel fuel. Characteristics of this palm oil derived diesel have been found to be quite close to those of petroleum derived diesel fuel.

Regarding the utilization of solid wastes, work is being carried out to study the techno-economic possibilities of replacing the present fixed-bed combustion system with a fluidized-bed combustion system to increase thermal efficiencies and improve the handling of the mill's energy system.

Gasification of these solid wastes as an alternative energy source for power production and vehicle fuels will also be looked at in the near future.

INTRODUCTION

Malaysia is the largest producer of palm oil products in the world, taking approximately a

Table 1. Total production of palm kernel oil and palm oil by Malaysia from 1978 to 1982 [1].

Year	Palm Kernel Oil ($x 10^6$ tonnes)	% of World Production	Palm Oil ($x 10^6$ tonnes)	% of World Production
1978	0.364	27.8	1.784	44.1
1979	0.470	32.4	2.188	48,6
1980	0.530	29.0	2.576	50.7
1981	0.589	31.4	2.824	52.4
1982	0.900	40.2	–	–

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55% share of the world's production in the year 1982 [1]. Table 1 shows total production of palm kernel oil and palm oil by Malaysia from 1978 to 1982. In 1985, Malaysia's production of palm oil increased to 4.15 million tonnes [2].

This paper reviews, briefly, works currently being carried out in Malaysia on the possibilities of utilizing palm oil products and wastes as alternative energy sources which is in line with the government's policy on diversification of energy sources.

PALM OIL AS AN ALTERNATIVE FUEL FOR DIESEL ENGINES

Initial work on the use of palm oil as an alternative vehicle fuel was undertaken at the University of Technology, Malaysia [3,4]. In the study undertaken, Refined Bleached and Deodorised (RBD) olein, easily available in the market as cooking oil, was used. The solid fat content in this RBD olein is very low at room temperatures.

The studies were performed on a single cylinder E-6 Ricardo diesel engine. The specifications of this engine are given in Table 2. Prior to the engine performance tests, studies on physical properties were conducted in compliance with ASTM D 975-81 specification for diesel fuel oils. The physical properties of palm oil are not very different from the properties of Grade 2 diesel fuel as specified by the Standards and Industrial Research Institute of Malaysia (SIRIM) [6] except that the former has a higher specific gravity and viscosity, and a lower cetane index and calorific value. The physical properties of the two types of fuels are compared in Table 3.

Table 2. Ricardo E-6 test engine specifications [4].

Single cylinder 4-stroke		
Water-cooled		
Swept volume	:	507 cc
Bore	:	76 mm
Stroke	:	11 1 mm
Maximum compression ratio	:	22/1
Direct fuel injection		
Wet sump type lubrication system		
Manufacturer: Ricardo & Company Ltd. Bridge Work, Shorham-By-Sea Sussex, England.		

It was concluded from these studies that palm oil is technically suitable for use in diesel engines. The power output of the engine using palm oil as fuel is higher than that of diesel fuel, as expected, since palm oil has a higher specific gravity, as shown in Fig. 1. However, a disadvantage of using palm oil as fuel is the higher fuel consumption rate as shown in Figs. 2 and 3, which leads to lower thermal efficiencies as compared to diesel fuel as shown in Fig. 4. Table 4 shows the results of exhaust emission analysis. The thermal efficiencies determined in this study are considerably less than those determined by Akor et al. [5] who obtained an average of 40.26 and 39.60 per cent for palm oil and palm kernel oil, respectively.

Table 3. Properties of palm oil, methyl ester produced from crude palm oil and Malaysian diesel fuels.

Test Methods	Properties	Palm Oil*	Methyl Ester+	Diesel	
				Grade 1+	Grade 2*
ASTM D445	Kinematic Viscosity, mm/s (@40°C)	6.36	4.5	4.0	1.6-6.0
ASTM D1298	Sp. Gravity (@ 40°C)	0.912	0.870	0.833	0.854
ASTM D976	Cetane number	38	50	53	46
ASTM D129	Sulphur content, wt %		0.04	0.5	1.5
ASTM D86	Distillation				
	I.B.P.	215	324	228	181
	10%	298	330	258	222
	50%	318	334	298	267
	90%	326	343	376	357
	F.B.P.	337	363	400	367
ASTM D2382	Calorific value (KJ/kg)	39357	40135	45800	45800

* Data from Ref. 2
+ Data from Ref. 4

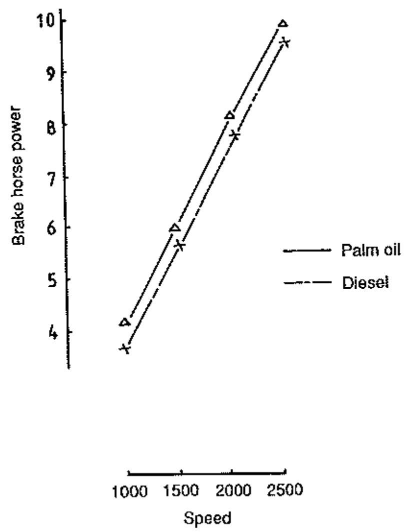


Fig. 1. Engine power output (extracted from Ref. 4).

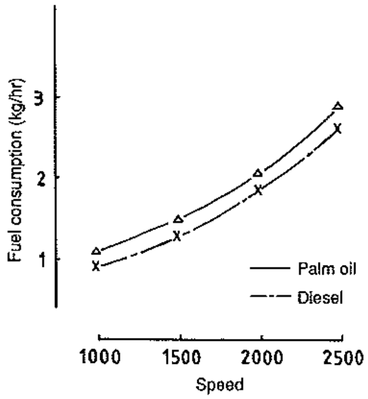


Fig. 2. Fuel Consumption (extracted from Ref. 4).

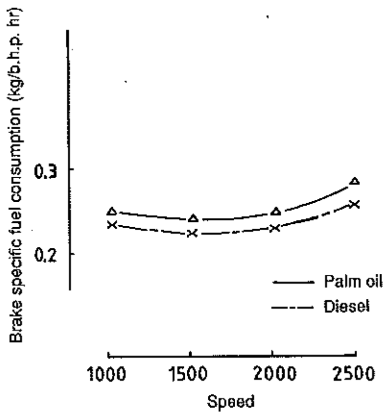


Fig. 3. Specific fuel consumption (extracted from Ref. 4).

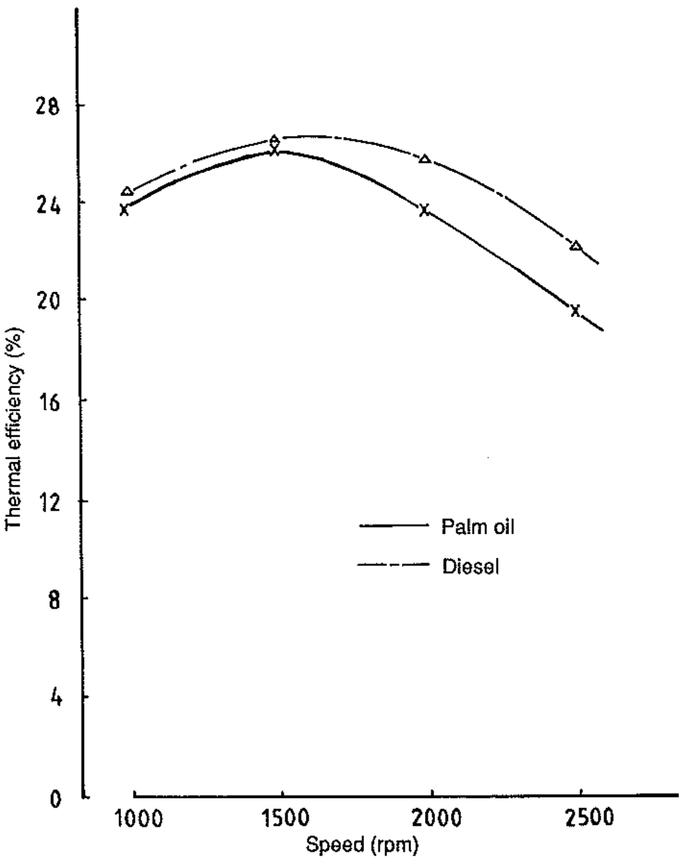


Fig. 4. Thermal efficiency (extracted from Ref. 4).

Table 4. Exhaust emission analysis.

Speed	Palm Oil			Diesel		
	CO_2	O_2	CO	CO_2	O_2	CO
1000	11.0	0.4	0.0	6.0	8.2	0.1
1500	9.2	0.6	0.0	4.8	7.2	0.0
2000	8.4	0.4	0.0	3.8	7.5	0.1
2500	7.8	0.4	0.1	3.4	7.4	0.1

A number of problems were also observed in the studies as anticipated because the engine was designed for use with diesel fuel. Among the problems noted were clogging in the fuel filter, nozzle deposits and corrosion.

An attempt has been made by the Palm Oil Research Institute of Malaysia (PORIM) to convert palm oil into methyl ester as an alternative fuel to diesel. The methyl ester produced showed improvements regarding certain physical properties of the fuel when compared to the original palm oil. Table 3 presents a comparison of the fuel properties of methyl ester produced from crude palm oil and a typical Grade I diesel fuel available in Malaysia [7].

Studies are being undertaken at present for engine performance using this methyl ester, however, no results have been published yet. The final assessment on the successful implementation of this alternative to diesel fuel will depend on the techno-economic viability.

ALTERNATIVE ENERGY SOURCE FROM PALM OIL WASTES

The oil palm processing industry is one of the biggest contributors of pollution in Malaysia with oil palm industrial effluent representing almost 46% of the country's contribution towards water pollution [8]. Beside this effluent which is produced by the processing mills, the industry also produces large amounts of other wastes in the form of empty fruit bunches (EFB), fibres and shells, which together represent approximately 50% of the original fresh fruit bunches (FFB).

Potential Energy from Palm Oil Solid Wastes

The estimates of wastes produced from 1 hectare of plantation are given in Table 5 [9]. Table 6 shows estimates of the annual total availability for EFB, fibres and shells from the year 1985 to 2000 based on dry weight, as estimated by PORIM [10]. These estimates show that the production of these wastes will increase steadily into the 1990's after which the level of production will almost be constant.

Results on the determination of calorific values [9,10,11] and proximate analyses [11] of these wastes are given in Table 7. An estimate of the potential energy that may be harnessed is given in Table 8 [12] based on a mill that processed 10.16 metric tonnes of FFB per hour. The total energy that may be produced is calculated assuming 30% process efficiency in transforming the raw material into useful energy. The total energy that may be harnessed from such a mill by utilization of the solid wastes is 3269.8 kW. With the total annual production of palm oil products of around 3.5 million metric tonnes in the year 1982, this would mean that the total potential

Table 5. Annual production estimates of oil-palm wastes from 1 hectare of plantation [3].

Total Fresh Fruit Bunches (ffbkg/hectare)	Waste By-products	Waste Production	
		kg/hectare	% ffb
18010	Empty fruit bunches	4490	25.0
	Fibres	2750	15.2
	Shell	1120	6.2
	Effluent (dry weight)	680	3.8

Table 6. Estimates of total annual availability of oil-palm waste for the years 1985 to 2000 (million metric tonne dry weight) [4].

Year	Empty Fruit Bunches	Fibre	Shell	Total
1985	1.600	1.666	0.962	4.228
1986	1.750	1.721	1.050	4.521
1987	1.870	1.953	1.127	4.95
1988	1.990	2.070	1.195	5.255
1989	2.090	2.178	1.195	5.463
1990	2.180	2.267	1.309	5.756
1991	2.230	2.328	1.315	5.873
1992	2.260	2.376	1.362	5.998
1993	2.230	2.376	1.371	5.977
1994	2.270	2.368	1.367	6.005
1995	2.270	2.364	1.364	5.998
1996	2.270	2.360	1.362	5.992
1997	2.230	2.349	1.356	5.935
1998	2.220	2.319	1.339	5.878
1999	2.200	2.297	1.325	5.822
2000	2.160	2.256	1.302	5.718

Table 7. Results of determination on calorific values and proximate analyses of oil palm wastes.

	Empty Fruit Bunches	Fibre	Shell
1. Proximate Analysis			
a. Volatile matter %	20 - 30	60.2-69.1	64-70
b. Ash %	1.3-1.6	2.1-2.5	1.4-6.2
c. Moistures %	61.4-72.9	28-28.9	9-11.7
d. Fixed Carbon %	5.6-7	4.6-8.0	17.2-19.6
2. Calorific value, MJ/kg	14.6	14.8	19.0

energy from the whole oil palm industry for the year 1982 was 1126.4 GWh which represents 10.6% of the total 10630 GWh of electricity produced by the National Electricity Board (LLN) of Malaysia in 1982 [13].

At present, all palm oil mills in Malaysia use fibre and shells as boiler fuels to produce steam for electricity generation and palm oil extraction processes, using conventional fixed bed combustors.

Apart from fibres and shells, EFB is another valuable biomass which can be used as an energy source. However, only a small proportion of it is being used as fuel for boiler. This is due to the pretreatment required for its bulkiness and high moisture content. At present, in most palm oil mills, the EFB is incinerated (as produced) for potash-rich ash which is used as a fertilizer. The heat energy generated is not utilized at all and thus valuable energy is wasted.

Work is being undertaken to study the feasibility of using fluidized-bed combustion to replace the present conventional technique so as to attain a more efficient utilization of these fuels [14]. It is envisaged that EFB will also be utilized for energy production with little or no pretreatment due to the flexibility of the FBC system.

Table 8. Potential energy from oil palm wastes from a mill processing 10.16 metric tonnes fresh fruit bunch per hour.

Wastes	Amount Produced (kg/h)		Calorific Value (KJ/kg)	Total Energy (that may be produced) (kW)
	Wet	Dry		
Shell	532	565	19000	894.6
Fibre	1551	1106	14800	1364.1
Empty fruit bunch	2533	831	14600	1011.1
			Total	3269.8

Biogas Energy from Palm Oil Mill Effluent (POME)

Beside solid wastes, the palm oil industry also generates a huge amount of highly polluting POME, the characteristics of which are given in Table 9. With more than 2.5 m^3 of POME generated for every tonne of palm oil production, more than 10.3 million cubic metres of POME was generated in 1985. The Department of Environment (DOE) requires POME to be treated to acceptable standards before it can be discharged (Table 9).

Being organic in nature, POME is easily amenable to biodegradation. In fact, anaerobic digestion is widely adopted by the palm oil industry as primary treatment for POME [15]. A valuable gaseous product – biogas is produced by this process. Biogas contains 60 - 70% methane, 30 - 40% carbon dioxide and trace amounts of hydrogen sulphide. Its properties are shown in Table 10 together with other gaseous fuels. About 28 cubic metres of biogas are produced for every cubic metre of POME treated. Hence in 1985 about 288 million cubic metres of biogas were produced. However, most of the biogas is not recovered and only a few mills harness the biogas for heat and electricity generation [16,17,18]. The potential energy from biogas generated by POME amounts

Table 9. Characteristics of palm oil mill effluent and Department of Environment standards.

Parameters*	POME	DOE standards
pH	4.0	5.0 - 9.0
BOD	25000	100 (50)+
Suspended solids	19000	400
Total Nitrogen	770	200++
Amoniacal Nitrogen	35	100++
Oil & Grease	8000	50
Temperature (°C)	80 - 90	45

* All parameters in mg/l except for pH and temperature.

\+ This additional limit is the arithmetic mean value determined on the basis of a minimum of four samples taken at least once a week for four weeks consecutively.

++Value on filtered sample.

to about 3.6 per cent of the national energy production. However, as all the mills are getting enough energy from fibre and shells, there is no outlet for this surplus energy.

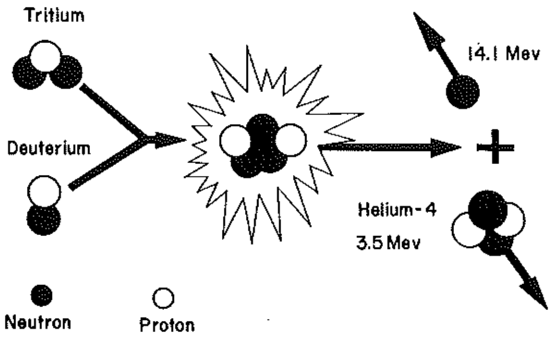
CONCLUSIONS

There is a high potential in Malaysia for the palm oil industry to provide alternative renewable energy sources from its main products and wastes. With fast depleting fossil fuel reserves, it is time for the relevant authorities or organisations to encourage and spread information concerning the economic opportunities of using these materials. Facilities and infracstructure to make such utilization viable should also be provided. Apart from saving large sums of money on energy bills and foreign exchange the problem of environmental pollution can also, to a certain extent, be alleviated.

REFERENCES

1. A Report by the Marketing and Industrial Economic Dept., Tropical Development and Research Institute, *Oil Palm Market Review* (1985).
2. Ma, A.N. and A.S.H Ong (1986), Biomass Energy from Palm Oil Industry, Paper presented at ASEAN *Conf. on Energy from Biomass,* Penang, 13 - 15 October 1986.
3. Ab. Rahim Ali (1983), *Palm Oil (Olein) as an Alternative Fuel for Diesel Engine,* Final Year Project, UTM.
4. Mohamad Afifi Abdul Mukti et al. (1984) Palm Oil as an Alternative Fuel for Diesel Engines, *PORIM Bulletin,* No. 9, November.
5. Akor, A. J., W.J. Chancellor and Nancy Raubach (1983), The Potential of Palm Oil as a Motor Fuel, *Trans. ASAE,* Vol. 26., No. 1, pp 23-28.
6. SIRIM MS 1.28:1973, *Specification for Diesel Fuels.*

7. Bohari Mohd. Yamin et al. (1986), Vegetable Oils as Alternative Fuels for Engines, Paper presented at *Energy Conservation Seminar*, 30 Sept., UKM, Selangor, Malaysia.
8. Godwin, S. (1980), Industrial Waste Water Management Programme in Malaysia, *Ind. Waste Water Control*, UPM, Serdang, Malaysia, July 1980.
9. *Statistics of Oil Palm, Coconut, Tea and Cocoa* (1981), The Dept. of Statistics, Kuala Lumpur, Malaysia.
10. Mohamad Husin (1985), Private Communication, PORIM, B.B.Bangi, Selangor, Malaysia.
11. Abd. Halim Shamsuddin (1985), Palm Oil By-products as Alternative Energy Source, Paper presented at *ASEAN Conf. on Energy Conservation*, 21 - 23 Oct. 1985, Chiang Mai, Thailand.
12. Poh, G.H. (1980), Alternative to Gasoline in Malaysia. Paper presented 21 - 23 August 1980.
13. *The Planter*, Kuala Lumpur, Vol. 57, pp 182 - 187, 1981.
14. Abd. Halim Shamsuddin and Tusirin Mohd. Nor (1985), Potential of Fluidized-Bed Technology for Combustion of Oil Palm Solid By-products, Paper presented at *Nat. Symp. on Oil Palm By-products for Agriculture Based Industries*, 5 - 6 Nov. 1985, PORIM, Kuala Lumpur.
15. Ma. A.N. et al. (1985), Palm Oil Mill Effluent Treatment – A Survey, *Proc of Reg. Workshops on Palm Oil Mill Techy. Effl. Treat*, PORIM, Kuala Lumpur.
16. Quah, S.K. et al. (1985), Sime Darby POME Treatment and Land Application System, *Proc. of Reg. Workshop on Palm Oil Mill Techy. Effl. Treat*, PORIM, Kuala Lumpur.
17. Gillies, D and S.K. Quah (1984),Tennamaran Biogas Project, Paper presented at the *2nd. ASEAN Workshop on Biogas Tech.*, 8 - 13 Oct. 1984, Kuala Trengganu, Malaysia.
18. Chuah, N.S. and H.L. Gian, Biogas Production and Utilization – Keng Seng's Experience. *Nat. Workshop on Recent Dev. in Palm Oil Milling Tech. & Pollution Cont.*, 5 - 6 Aug., Kuala Lumpur.



HOW FUSION WORKS

The simplest fusion reaction is the fusing of two hydrogen nuclei, which produces one helium nucleus and liberates energy. In the deuterium-tritium fusion process shown here, a deuterium nucleus (one neutron and one proton) fuses with a tritium nucleus (one proton and two neutrons). Two protons and two neutrons combine to form a stable helium nucleus, while the extra free neutron flies off with four-fifths of the total energy released as kinetic energy. (The stable helium atom has the remaining one-fifth of the energy.) This kinetic energy can then be converted to heat or electricity. The energy needed to start the deuterium-tritium reaction is 10 million electron volts (megavolts), while the energy produced is 17.6 million electron volts.

Fig. 1. How fusion works.

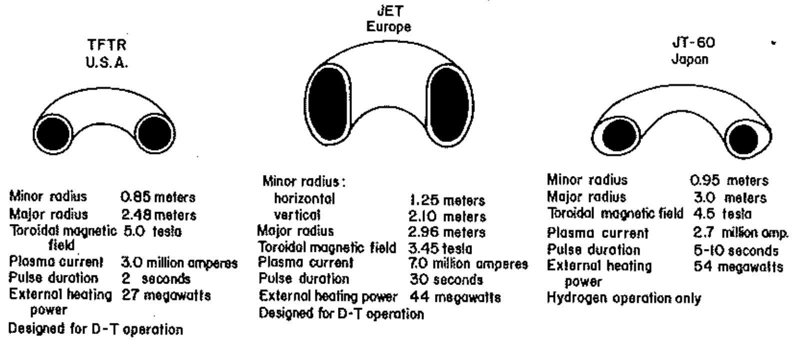


Fig. 2. The three largest tokamaks compared.

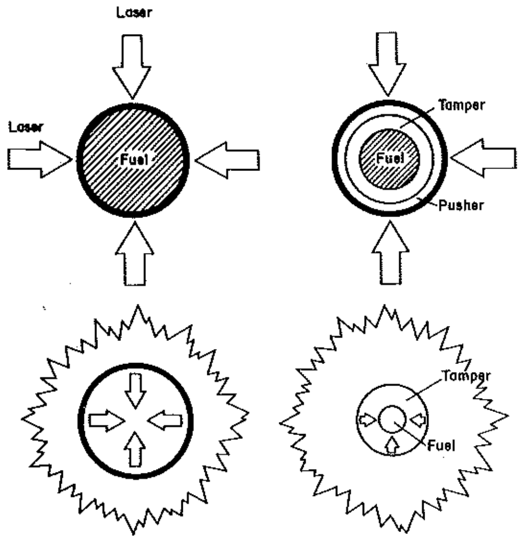


Fig. 3. The principle of laser fusion: laser light in a time span of nanosecond range illuminates and compresses the fusion fuel (D-T) to achieve fusion.

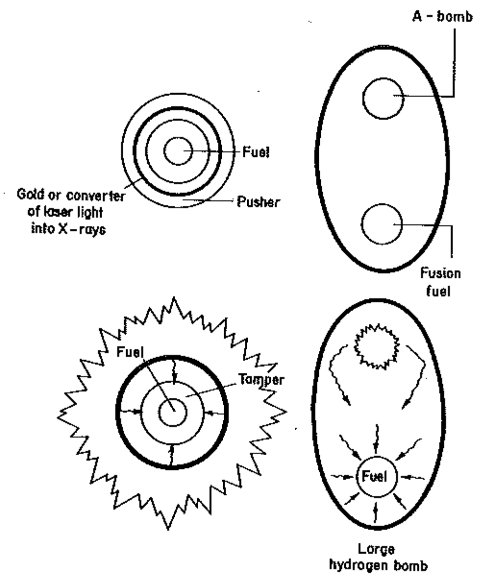


Fig. 4. Advanced laser fusion targets: these targets work according to the same principle as the H-bomb; laser energy is converted into x-rays, which compress the fuel nearly isentropically to achieve fusion.

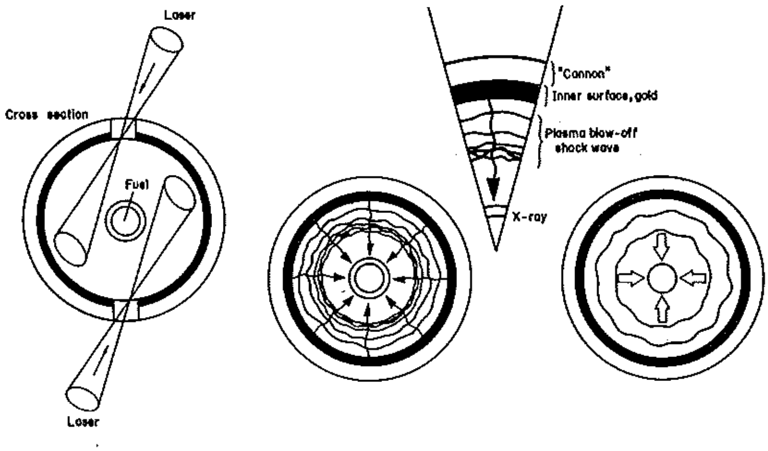


Fig. 5. The Osaka cannonball - a nonablative laser fusion target.

engineering test facilities for magnetic fusion could come on line during the second half of the 1990s and fusion-based central electric power stations will almost certainly be realized during the first decade of the next century.

The easiest fusion reaction to ignite is that of deuterium-tritium:

$$D + T = He\text{-}4 + n \ (17.6 MeV) \qquad (1)$$

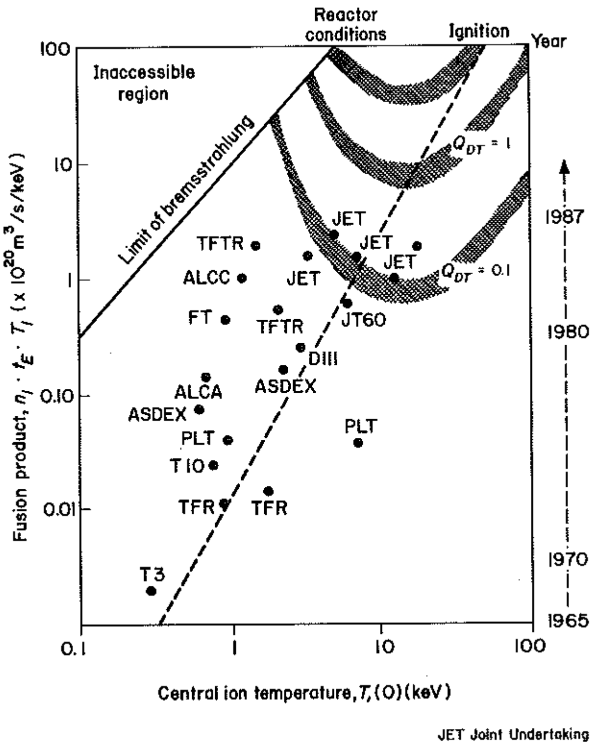


Fig. 6. Progress of fusion experiments in tokamak devices.

In this case, the two heavy hydrogen isotopes fuse to form the next heavier element, helium-4. It is principally their reaction, which is being experimented within the Tokamak Fusion Test Reactor (TFTR) at the Princeton Plasma Physics Laboratory (USA) and the Joint European Torus (JET) in Culham, England.

The next easiest reaction to ignite is that of deuterium-deuterium, which involves two possible paths, each occurring at about the same rate:

$$D + D = He\text{-}3 + n\ (3.2\ MeV) \qquad (2a)$$

or

$$D + D = T + p\ (4.0\ MeV), \qquad (2b)$$

where the products are either helium-3 and a 2.45 MeV neutron (n) or a tritium nucleus and a proton (p). These reactions are relevant to the F/P experiments.

Other possible reactions, that may also eventually have to be considered in the case of cold fusion, are :

$$D + He\text{-}3 = He\text{-}4 + p\ (18.3\ MeV) \qquad (3)$$

and

$$Li\text{-}6 + D = Li\text{-}7 + p\ (5.0\ MeV) \qquad (4)$$

where lithium-6 and lithium-7 are isotopes of the chemical element following helium.

With these preliminaries out of the way, let us now turn to the cold fusion experiments. But first note again that, until the announcement of the F/P results, the above fusion reactions were only considered realizable at extremely high temperatures (particle velocities) and with the aid of machines costing hundreds of millions of dollars to construct. This explains the shock effect and disbelief produced by the "fusion in a jar" claims.

The Fleischmann/Pons Experiment

The relatively simple F/P experimental set-up (not taking into account the more sophisticated diagnostic instruments) is shown in Fig. 7.

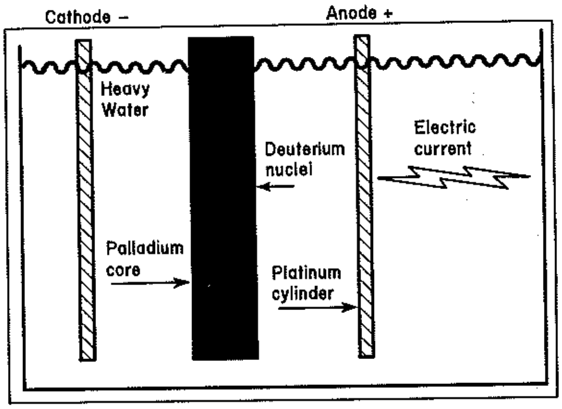


Fig. 7. Simple F/P experimental set up.

In their paper "Electrochemically Induced Nuclear Fusion of Deuterium"[1)], F/P describe their observations and measurements as a current is passed through the D_2O/electrolyte solution, saying most importantly that:

1) "Enthalpy generation can exceed 10 W/cm^3 of the palladium electrode; this is maintained for experimental times in excess of 120 hours during which typically heat in excess of 4 MJ/cm^3 of electrode volume was liberated. It is inconceivable that this could be due to anything but nuclear processes. " [?] [Emphasis added]
2) "... the γ - ray spectra which have been recorded in regions above the water bath adjacent to the electrolytic cells... confirm that 2.45 MeV neutrons are generated in the electrodes by the reaction

$$^2D + ^2D \quad = \quad ^3He\ (0.82\ MeV) + n\ (2.45\ MeV) \qquad [cf.(2a)\ above].$$

... We note that the intensities of the spectra [and thus the neutron flux] are weak.." [Emphasis added].

So, is it really fusion? And if so, how to explain it? F/P have challenged scientists around the world to replicate their experiments and "fusion jars" have probably been set up in nearly 100 laboratories worldwide. So far the results reported are contradictory and thus inconclusive, though at least the obvious control experiments of replacing D_2O with H_2O in the eletrolytic cell have shown no significant heat generation. Thus it is certainly the deposition of deuterium in the palladium electrode that is responsible for the F/P effect.

But again, is it really D-D fusion that is responsible for the electrode heating? The wisecrack of a fusion scientist that if it were fusion then F/P should be dead, points to a major theoretical dilemma:

The large amount of heat generated is not accompanied by an anywhere near large enough neutron flux to make a convincing prima facie case for fusion. The author does not believe that the cold fusion controversy will be resolved decisively until scientists begin to formulate coherent scientific hypotheses and design crucial experiments capable of shedding light on and explaining the high heat/low neutron count paradox. The rather few and very preliminary attempts that have been made to come to grips with cold fusion in theoretical terms are reviewed below.

Some Theoretical Considerations

Current fusion theory stipulates that significant rates of fusion of heavy hydrogen nuclei require temperatures approximating 100 million °C, with ignition of self-sustaining fusion reactions becoming possible only when the product of the ion density (particles per unit volume) and confinement time exceeds $5x10^{22}$ s/m^3. Such extreme conditions are, of course, not relevant to cold fusion. At room-temperature nuclei are clothed with electrons and the rate of fusion in molecular hydrogen is governed by the probability of zero separation of two nuclei (quantum - mechanical tunneling through the Coulomb barrier). For the deuterium molecule, equilibrium separation between deuterons is equal to 0.74 Å with a "natural" fusion rate calculated at about 10^{-70} per D_2 molecule per second.

The question thus arises how this exceeding slow rate could be massively increased (by, say, at least 50 and up to 80 orders of magnitude), without great increase in temperature (particle velocity), in order for cold fusion to be accounted for. Or, to be more specific, what is it about confinement of deuterons in a metal lattice that would make them fuse in a low temperature regime? Two hypotheses, exemplifying some current thinking, are as follows:

1) S.E. Jones et al.[2)], Brigham Young University, USA:

   What happens in the case of cold fusion may be comparable to muon catalyzed fusion. By replacing the electron in a hydrogen molecular ion with a more massive muon, the internuclear separation is reduced by a factor of 200 (the muon to electron mass ratio), and the nuclear fusion rate correspondingly increases by roughly eighty orders of magnitude. This extraordinary variation in the magnitude of the fusion rate leads one to suspect that even small perturbations of the hydrogen molecule's wave function could result in a dramatic change in the spontaneous fusion rate. Imposing boundary conditions on the H-molecule's nuclear wave function simulating the confinement of nuclei within a lattice cell, a fusion rate of the order of 10^{-24} /s is calculated. This fusion rate conforms to the actually measured neutron flux from cold fusion experiments carried out at Brigham Young University.

Commentary:

The Jones hypothesis is interesting, but has two pitfalls. First, a rate of 10^{-24} is too slow to explain the F/P results. Second, if wave function boundary conditions could be found to account for the F/P effects, a very high neutron count would likely also be implied – contradicting the F/P findings.

2) H. Aspden [3], University of Southampton, England:
The hypothesis is twofold:
a) A new theory of gravitation that has yielded an accurate theoretical evaluation of the constant of gravitation and has been shown to have relevance to the phenomenon of warm superconductivity, applies to cold fusion as well. The theory distinguishes between normal gravitons balancing matter of mass-energy 6.149 GeV and supergravitons balancing matter of mass-energy 95.17 GeV. The proposition is that when deuterons leave the heavy water environment and enter the dense matter environment (palladium, titanium) their normal gravitons have about one microsecond in which to merge into the supergravition state. During the one microsecond period after absorption into the dense matter the deuterons are vulnerable to the vacuum field energy fluctuations associated with the graviton transition and sufficient energy is conferred upon them to catalyze deuterium-deuterium fusion.
b) No significant neutron flux is observed, because there are no neutrons in stable matter, but only metastable antiproton/positron combinations.

Commentary:

Even a rather cursory evaluation of the Aspden dual hypothesis would go well beyond the scope of this paper. The hypothesis is presented here to demonstrate that a full explanation of cold fusion will almost certainly involve some entirely new theoretical accounts of the atomic nucleus and of the interaction of electro-magnetic phenomena with the geometry of space/time. This makes cold fusion not only experimentally challenging but – perhaps along with warm superconductivity – will catalyze badly needed new impulses in theoretical physics. Every scientist should welcome the implied theoretical challenges and opportunities for potentially revolutionary innovations.

CONCLUSIONS

The present status of the cold fusion controversy can be fairly summed up as follows:

1. Extraordinary amounts of heat production in F/P-type experiments have been observed not only by F/P themselves, but by numerous researchers attempting to replicate the University of Utah experiments. No electro-chemical explanations are available to account for the observed phenomena.
2. Nuclear reactions provide for the most plausible alternative account. However, the lack of sufficient neutron production puts the nuclear fusion hypothesis in doubt.

The scientific community's reaction to this dilemma, so far, has been most disappointing. Tinkering with the F/P experimental set-up or petty and cynical comments from fusion researchers worried about competition for funding of their own established projects will not make the controversy go away. Too much is at stake, both for science and for the future of humanity at large. Heavy water is cheap and abundant, constituting one part of 6500 of ordinary sea water. Just imagine the economic opportunities and consequences implied by virtually unlimited, cheap and clean energy production!

So, the challenge to scientists is clear: Formulate hypotheses and design experiments capable of clarifying the dispute. Instead of taking sides himself, the author will paraphrase the recent comment on cold fusion by one of the world's most senior fusion scientists, Edward Teller, who, admirably, has never allowed alleged unassailable theories to blind him to contrary evidence:

"Before the Fleischmann/Pons presentation (March 23) of their results I regarded cold fusion as horrible nonsense; now I am happy to think that I may have been horribly wrong."

REFERENCES

1) Fleischmann, M. and S. Pons (1989), Electrochemical Induced Nuclear Fusion of Deuterium, *J. Electroanal. Chem.*, No.261, pp.301-308.
2) Jones, S.E. et al., *Cold Nuclear Fusion in Condensed Matter* and *Theoretical Limits on Cold Fusion in Condensed Matter*. (Unpublished manuscripts, Mar. 23 and Mar. 27,1989).
3) Aspden, H., *Cold Fusion as a Supergravition Transition.* (Unpublished manuscript).

A Note on the Analysis of Solar Insolation over Karachi – Pakistan

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Raja, Twidell and Abidi [1] studied the Ångström correlation for global radiation and sunshine duration data recorded at Karachi with a view to employing this to estimate solar radiation at nearby locations. They obtained monthly values of the correlation parameters a and b for the relation

$$H/H_0 = a + b \ (n/N) \tag{1}$$

where H is the daily extraterrestrial radiation, H_0 is the daily global insolation, n is the duration (in hours) of daily bright sunshine and N is the day length. The authors found that the parameter a has monthly values in the range 0.031-0.200 while b has values between 0.565 and 0.914. The sum $a + b$ exceeds unity for some months, the correlation coefficient r varies from 0.57 to 0.89 and the r.m.s. error is 0.40 MJ/m^2-day.

We find that the monthly data presented by the authors give an Ångström type fit over the year with $a = 0.323$, $b = 0.385$, $r = 0.89$ and r.m.s. error = 0.43 MJ/m^2-day. As it has been found [2-4] that seasonal effects may be taken into consideration for precise estimations we prefer to divide the year into monsoon and off-monsoon months for Karachi region. For monsoon months i.e., July, August and September, we obtain $a = 0.366$, $b = 0.282$, and $r = 0.90$ and for the rest of the year $a = 0.316$, $b = 0.396$, $r = 0.92$ while the r.m.s. error over the year is 0.40 MJ/m^2-day.

As is well known, the relation (1) leads to the conclusion that $a + b$ represents H/H_0 for clear sky condition and hence the sum can not exceed unity. Again a equals H/H_0 under an overcast sky and this normally has a value above 0.2. Hence some of the figures for a and b obtained by Raja et al. are not consistent with above interpretations of the Ångström parameters. Both the fits using average monthly data over the year with and without seasonal effects agree with such interpretations. The seasonal fits give slightly smaller errors. Again temporal variations in atmospheric turbidity, precipitable water amount and surface albedo call for seasonal partitioning of data [2].

REFERENCES

1. Raja, I.A., J.W. Twidell and S.B.H. Abidi (1988), Analysis of Solar Insolation over Karachi (Pakistan), *RERIC International Energy Journal*, Vol.10, No. 2, p.75.
2. Hussain, M. (1984), Improved Estimation of Solar Irradiation from Sunshine Duration Using Meteorological Constraints, *Proc. ENERGEX Conf.*, Regina, Canada, pp.393-396.
3. Benson, R.B., M.V. Paris, J.E. Sherry and C.G. Justus (1984), Estimation of Daily and Monthly Direct, Diffuse and Global Solar Radiation from Sunshine Duration Measurements, *Solar Energy*, Vol.32, pp.523-535.
4. Becker, R. (1987), Monthly Average Solar Radiation in Panama – Daily and Hourly Relations between Direct and Global Insolation, *Solar Energy*, Vol.39, pp.445-453.

Reply to Professor Hussain's Note on Analysis of Solar Insolation over Karachi – Pakistan

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I am thankful to Prof. Hussain for his comments and useful suggestions to improve further the above study. I agree that the sum of coefficients a and b must not exceed unity. While in the study under discussion it does for the months of July and August. The overcast sky and clear sky conditions of $H/H_0 = a$ and $H/H_0 = a + b$, respectively also seem to be violated and the results show inconsistency in some instances. On the basis of the recent scrutiny of the daily data of the sunshine hours, it is believed that the poor correspondence between the coefficients a and b and the data is due to the type of the sunshine recorder used and the human practice in obtaining the data. Campbell-Stokes recorders are used in all observatories. The instruments suffer from the drawback that the card does not burn until the insolation intensity reaches a certain critical value. Hay [1] suggested a 5 degree (sunset and sunrise) correction to the daylength to correct for this. However we have applied a 4 degree correction on the basis of having clear mornings and evenings. It is found that the bright sunshine duration (in hours) exceeds the actual daylength for certain days (human error). The number of such unusual cases are around 10%, when a 4 degree corrected daylength is considered. In our study we have used the actual measured data, which possibly might have led to the discrepancies. However, our results are not unique. Iqbal [2] reported for Resolute $a = 0.319$ and $b = 0.683$, where the sum $a + b > 1$. I intend to revise our study with daily values after reconstructing the data.

Prof. Hussain suggested the inclusion of seasonal effects, particularly monsoons. Pakistan receives only the tail end of monsoons. Thus the monsoon season is neither as prolonged nor as wet as that in India [3] and Bangladesh. Therefore, it will not affect the results considerably. Also one of the basic advantages of using the Ångström relation is that the variations of climate appear in the regression coefficients themselves [4]. The coefficients thus obtained using annual mean data or seasonal data or the daily data, would account for the climatic variations within that specific period. It is understood that the climatic variations are less within a month than in the season or in the year as a whole. Therefore the seasonal coefficients could not produce better results than those of monthly. Prof. Hussain obtained the seasonal values of the coefficients a and b using only three data points. Statistically this is not appropriate. However, we intend to carry out the analysis on a seasonal/daily basis, using daily data. This will provide a reasonable and statistically appropriate number of data points for the regression analyses. The annual mean regression analyses have already been done [5,6]. The values obtained are:

$a = 0.327$ with sunshine record 1951-87
$b = 0.368$ and insolation record 1957-61
$r = 0.98$ and 1966-87

and

$a = 0.324$ with sunshine record 1969-85
$b = 0.384$ and insolation record 1957-61
$r = 0.98$ and 1966-84

These results agree with Prof. Hussain's analysis, except for the correlation coefficient.

REFERENCES

1. Hay, J.E. (1979), Calculation of Monthly Mean Solar Radiation for Horizontal and Inclined Surfaces, *Solar Energy*, Vol. 23, No.4, pp.301-307.
2. Iqbal, M. (1983), *An Introduction to Solar Radiation*, Academic Press, Canada.
3. Fazle Karim, M. (1984), *Pakistan: An Economic Geography*, Sir Sayyed Academy, Karachi, Pakistan.
4. Page, J.K. (1964), The Estimation of Monthly Mean Values of the Daily Total Short Wave Radiation on Vertical and Inclined Surfaces from Sunshine Records for Latitudes 40 °N-40°S, *Proceedings of the UN Conference on New Sources of Energy*, Vol.4, Paper No. S/98, pp.378-387.
5. Raja, I.A. and J.W. Twidell, Iso-Sunshine Maps and Correlations for Predicting Global Insolation for Pakistan, *RERIC International Energy Journal*, submitted.
6. Raja, I.A., S.B.H. Abidi and J.W. Twidell (1989), Correlation for the Prediction of Monthly Average Daily Global and Diffuse Radiation over Karachi, Pakistan, *9th Miami International Conference on Alternative Energy Sources*, 11-13 December 1989, Miami Beach, Florida, USA.