Indian Combustion Science and Technology - ICST @ 2013

The highs and lows of the past and how to make lows high?

- Sectors addressed: Space, aeronautics, transportation, energy – coal and biomass, fire safety, energy-environment nexus.
- Space and Aeronautics - Highs in both in S & T – any new ideas?
- Energy -Coal and biomass – The lows in Coal, biomass high in new S & T
- Energy and economy + energy research and rural q-o-l — much to do
- Engine research - the lows and how to make it high
- Highs in Combustion science and lows in Fire science research
- Energy and environment – new issues requiring national perspectives.

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Space and Aeronautical propulsion

- The growth of Indian aeronautics remained stifled with purchases of good hardware from the Soviet union (later from Russia) till the formation of ADA with much struggle and strife.
- The team delivered the aircraft against many odds. They had to pick GE engine for the Indian engine development was in its infancy.
- The development of rockets for launching sounding rockets had significant inputs into solid rockets from overseas. Further development of all propulsion was largely indigenous.
- The situation with missiles was no different. Indigenous efforts are ignored if possible, side stepped if it could be and challenged where possible unless it was clear things have to be procured from within.
- This was significantly due to technology denial – informal and formal. I would say:

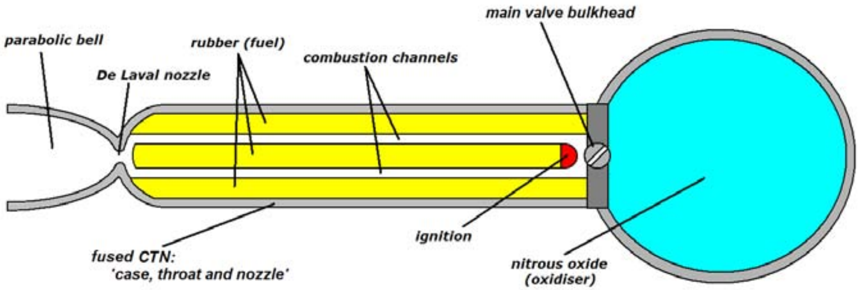
  Blessed are those who want to and have to get to the frontier themselves. Struggle it may be, but most satisfying and gratifying will it be as times have shown.

Combustion of propellants?

- Studies of various levels of sophistication have been completed in ISRO, DRDO and academic institutes on steady burn rate behavior in solids, liquids and hybrid propulsion systems.
- It is not adequately recognized that combustion in liquid propellants and hybrids can be understood in simpler ways because they are diffusion limited.
- Combustion of composite solid propellants presents complexities due to interaction of chemistry – gas phase and surface along with melt layer effects. These challenges are still being examined today.
- Research on these aspects has gone muted or out-of-vogue in the USA due to a combination of influences – (a) doers don't seem to want to know more and (b) those who want to do have less new challenges due to down-turn of economy and the country itself having to deal with more compelling issues…global environmental matters……..reduced emphasis in the USA implies snowballing effects on high rated publications.
- But then, aren't new things taking place in the USA and can't new things be done here…

New things of substance in the USA and what is possible in India

- Low cost access to space in 2013+ is nearly like opening up aircraft service in 1939!
- Low cost access to space is an important agenda item - more than moon mission is a view I have held for long time - no reason to change my view, yet.
- SpaceShip1 designed by Burt Rutan. The rocket that took the air-launched space plane with a pilot to 100 km altitude and returned safely and won the 10 million dollar X-prize in 2004. It uses hybrid rocket for the space segment.



- Hybrid rocket is one of the safest propulsion systems.
- Uses polymeric fuel and nitrous oxide as the oxidizer.
- These are low energy propellants.

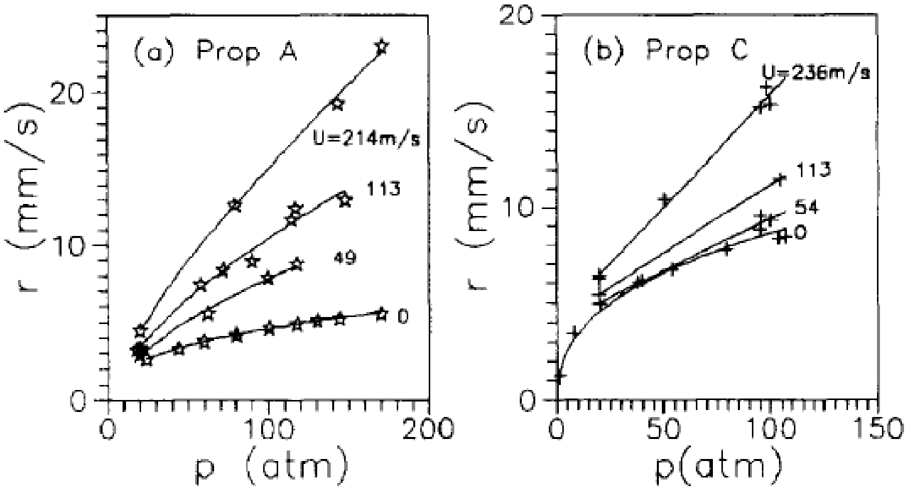
……………………..Why am I saying all these?

....what was done in India

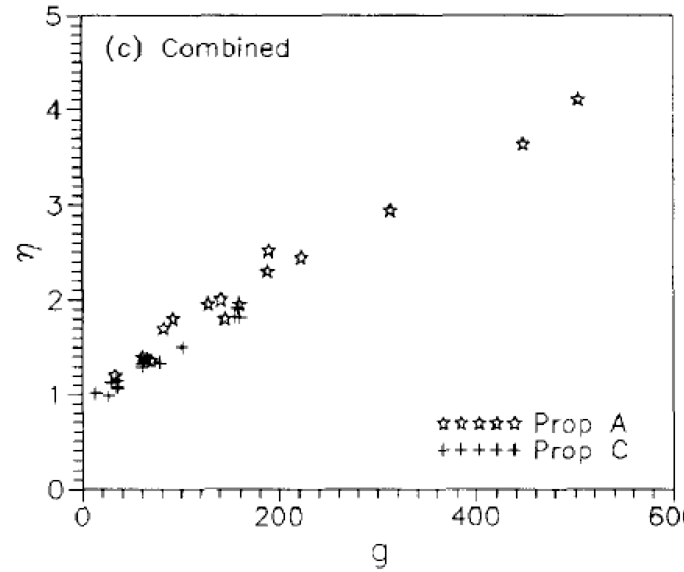
- Between 1970 to 1980, an ARDB sanctioned project was completed in IISc wherein hybrid propulsion systems were researched and scaled motor tests with LOX-polymeric fuels were conducted successfully.
- At the end of this, ISRO was offered the technology option for space applications by IISc – reason: better safety and low cost of propellants at comparable performance. Of course, these did not find even the minimum favor. General pooh-poohing was there.
  - I expect it is extraordinarily difficult to be visionary.
- A study was conducted to determine the most promising approach to low cost access to space and published [N. Jayan, K. S. Biju Kumar, A. K. Gupta, A. K. Kashyap, K. Venkatraman, J. Mathew, H. S. Mukunda, Studies on an aerial propellant transfer space plane (APTSP), Acta Astronautica 54 (7), 519-526, 2004]
- A formal presentation also took place in 2009 as a part of INAE activities to a large group arguing that the rocket propulsion system has to be far more energetic that that used in SpacShip1 since it controls the payload fraction significantly (recognize that $\Delta V \sim 8$ km/s is largely controlled by space segment)
- The earlier knowledge base could be capitalized even at that time if the subject of low cost access to space that holds the key to large scale space-commercial actions be revitalized. The country could be a leader rather than a follower – However, the matter stopped at that.
- The closed chapter has been reopened with greater advances in terms of new oxidizers (H_2O!) and fuels (Highly aluminized – 50 % Al-solid propellant) by Prof. P. A. Ramakrishna (IITM). It is certainly more attractive for naval weapons – torpedoes (a subject I spent some time long time ago).
  I hope this will receive more attention.

…..Done in India

- Way back in 1972-1974, DRDL (Wg. Cdr A R Vaidya) wanted the erosive burning in specific solid propellants to be evaluated and gave a project.
- This started my interest in the subject of erosive burning. Led to my deeper love for the subject.
  Result: A scientific work of practical value.



Results of Marklund and Lake, 1960



H. S. Mukunda and P. J. Paul, 1997

$$\eta = 1 + 0.023(g^{0.8} - g_{th}^{0.8})\mathscr{H}(g - g_{th}), \quad (12)$$

where $g = g_0(\mathrm{Re}_0/1000)^{-0.125}$ and $g_{th} = 35.0$.

…Some productive interactions

- The universal correlation can be and has been used for design.
- A very useful extension to the study underlying this relationship was made recently with useful interaction with DRDL scientists.
- This contribution would not have happened were it not for the kick-starting by Dr. Vaidya in 1972!.
- Perhaps, designers would be using some relationship of a "western scientist" happily (and many are tempted even now)
- Occasionally, I am required to "defend" the universal relationship even now!

- Conclusion – what I also stated in 2008 at the Golden jubilee at DRDL –

Think, find a committed person (from your perspective) and give money for research. You may not know the extent of benefit and even the investigator may not know; the pathways of academic research are sometimes inscrutable

ISRO and DRDO – commonalities and differences

- GSAT and AGNI are comparable strategic missions of ISRO and DRDO.
- Strategic missions have always higher priority and higher measure of public owning of the strengths of the organizations.
- Demands of Defense tactical systems go beyond ISRO's systems:

  – The propulsion systems of Prithvi, Akash, P, B etc need qualification at -30 to +70 °C and the systems must have long proven life.

  – Propulsion system requirements of "no smoke" causes the choice of the propellant that may be more susceptible to instabilities. We must remember that the system must be made dynamically "stable".

  – The number of tactical systems is very large. – has production and reliability issues of much higher significance. Users and producers are different.
- There are genuine worries here. For, I have not been able to see the rigor in propulsion system development and documentation needed to meet the challenge.

Two examples on reliability and performance

Soyuz – one flight a week for 22 years - more than 1000 launches with a reliability exceeding 0.995!

Mars Science Laboratory - Curiosity,– JPL, Ca, USA

….The view from inside Gale Crater, the landing place of the rover Curiosity. Eight months after touching down safely, the rover has already found an ancient lake bed laced with carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur—the building blocks of life.

"Building the system, carrying out the launch operations, manage the landing sequence on Mars needed establishing reliable system elements for over a decade with about 45 scientists and tens of manufacturing units".

……the most complex and technically daring landing sequence in the history of the space program….

Report: 22 April 2013 from NewYorker

More things that are path-breaking are being conceived and progressed in difficult times ahead……..Can't we also do things of "scale" of frontier nature?

Energy -Coal and biomass – Coal lows, biomass high in new Science & Technology

- Internationally, solid fuels are much less addressed compared to liquid fuels and gaseous fuels.
- For instance, a simple analysis of the papers in International combustion symposia show that the ratio of papers published for gaseous fuels, liquid fuels and solid fuels is 100:90:20
- Complexities of solid fuels are due to shape, size and moisture effects beyond liquid and gaseous fuels

Coal and Biomass – commonalities and differences

- Biomass is the origin of coal – Biomass processed geologically at very high pressures and temperatures results in coal.
- Both are composed of C, H, N, O and ash.
- Ash in biomass is about 1 to 5 % (rice husk/straw have 20 % ash); Ash in coal is 5 to 45 %. Indian coals have higher ash content.
- Biomass has little or no sulfur. Coal has sulfur – Indian coals about 0.5 % and Australian and Malaysian coals – up to 3 %.
- Biomass under heat releases 75 to 80 % volatiles; coal releases 25 to 30 % volatiles.
- This implies biomass energy release is much more in g-phase.
- Coal is handled as large pieces with combustion on grate; also, it is pulverized to fine powder to be burnt in special burners in power stations generating steam power.
- Biomass is <u>largely</u> a domestic fuel. It is also used in industrial settings with combustion on grate as well as fluidized bed combustion systems.

Coal and biomass-to-power, commonalities and differences

- Coal (of 25 to 40 % ash) is used in steam power units at 200 to 1000 MWe class systems at 550 mmt (million metric tonnes) in India at solid fuel-to-heat efficiencies of 75 to 80 % and solid fuel-to-electricity efficiencies of 36.5 % (max)
- Biomass – firewood (250 mmt), agricultural residues (120 mmt) and cowdung (90 mmt) – a total of 460 mmt is used in over 120 million households in India at solid fuel-to-cooking pot efficiencies of ~ 15 %.
- Biomass-to-electricity systems at 4 to 10 MWe have efficiencies of 25 to 27 %.
- There is considerable interest to raise solid fuel-to-electricity efficiencies by additional 4 to 8 % through the use of new technology.
- The new technology aims at converting the solid fuel into a gaseous fuel. These can be done at ambient pressure or high pressure. The reacting oxidizer can be air, enriched air or oxygen.
- These devices are termed gasifiers. The gas so produced is burnt in internal combustion engines – gas turbines or reciprocating engines. The residual heat from these engines that is much more in gas turbines is used to generate steam power (HRSG)
- Such technologies go under the name "clean coal technologies"

………really what are they?

What is clean coal technology? Why?

- India is strong at steam generation based technologies – BHEL & NTPC. Other players include Thermax and ….
- The order books for 100 to 1000 MWe from this country and overseas are full for several years.
- Clean coal technology is the one in which emissions are minimal and efficiency is high. This efficiency must go beyond the currently achieved values in thermal power systems (~36.5 %)
- Both sulphur primarily and NO_x emissions must be reduced.
- Fortunately, since Indian coals have small sulphur this will not be a serious issue. However, a wide range of coals – Malaysian, Indonesian and Australian may need to be dealt with.
- Clean up before combustion is always more effective than post operations clean-up. This is also because the amount of matter to be dealt with is much less in the early stages than towards the end.
- World-wise, it is understood that integrated gasification combined cycle is the answer. Better efficiencies (~ 40 %) and better emission control strategy.

Simple benefits of reducing ash in coals – coal beneficiation – Satpura thermal power station (NTPC)

- Uses washed coal of 34% ash in 1 x 210 MWe unit.
- Plant Load Factor increased from 73% to 96%
- Coal consumption reduced by 29% (**from 0.8 to 0.6 kg coal/kWh**)
- Reduction in Auxiliary Power Consumption (~1.5%)
- Reduction in down time of mills
- **No fuel oil support**
- Boiler efficiency improvement by 3%
- Coal mill power consumption (kWh) reduced by 48% reduction
- Savings by using washed coal of Rs 43 million/yr (2.4 paise /kWh).

More on… why gasification if combustion is OK

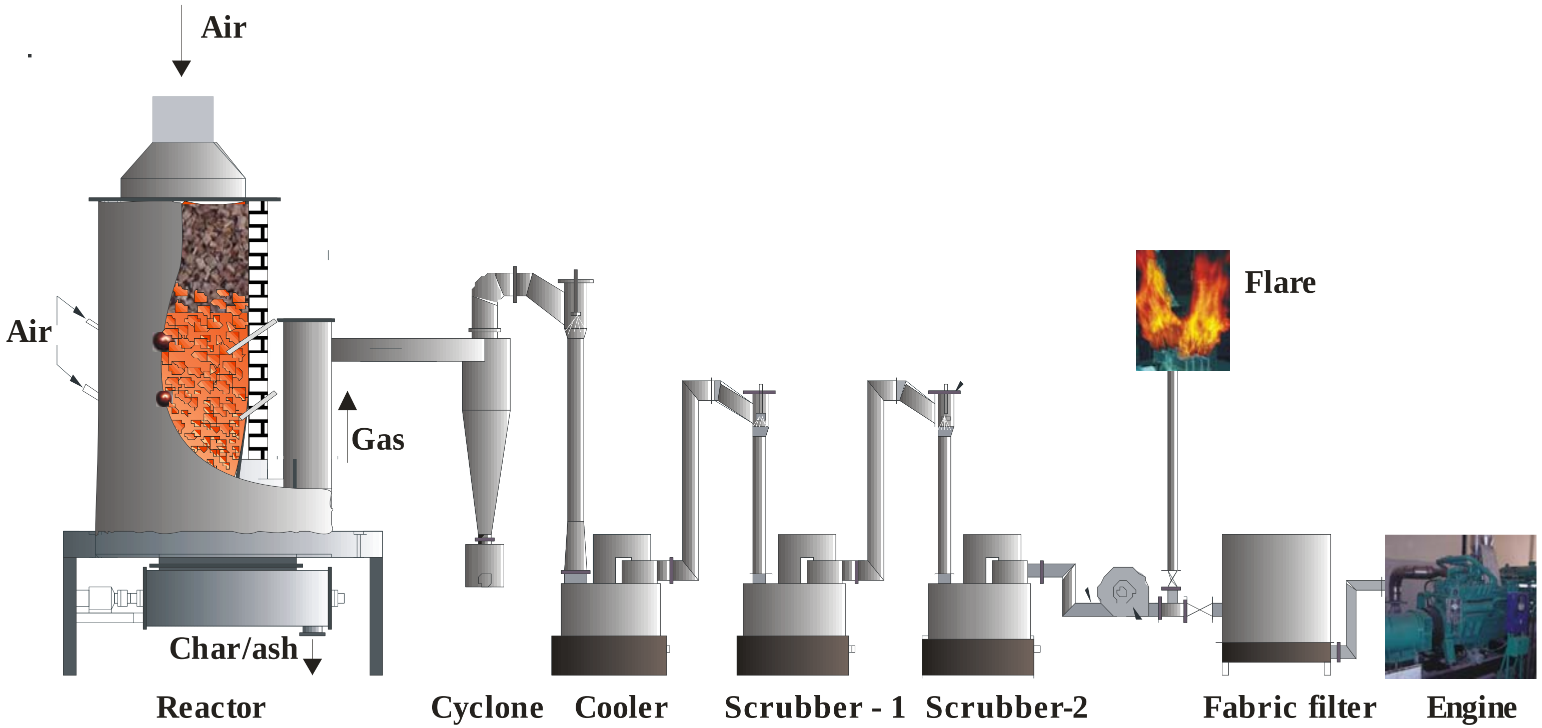
- **Combustion process** leads to products – CO_2, H_2O, NO_x, SO_x etc
- The best fuel-to-electricity efficiencies using high pressure steam turbine route are ~36.5 % in India. There is considerable interest to increase it to 37 % if possible. There are technical and engineering issues in this effort.

- **Gasification** produces a gaseous fuel from the solid fuel – CO (20 to 25%, H_2 (12 to 15 %), CH_4 (2 to 3 %), CO_2 (10 to 15 %), H_2O (2 % in cold gas), H_2S (depends on sulphur content in the coal, typically, 100 to 1000 ppm), rest N_2.
- If high pressure gasification is adopted, the gas is taken into a gas turbine and power is generated. The downstream hot gases are used to generate steam power (Heat Recovery Steam Generator)This is called IGCC – integrated gasification combined cycle route. It promises 33 + 13 ~ 46 % efficiency. This technology is expensive (Rs 11 crore/MWe compared to Rs.7 crore/MWe classical).
- The technology becomes economical only at ~100 MWe +

- An alternate is to use ambient pressure gasification and use reciprocating engines. One can also integrate HRST into this strategy. This is new – not tried yet

Work at BHEL has not gone much beyond this level of development except in terms of documents.

New gasification technologies (1) biomass



- A staged air-ingestion open top reburn multi-fuel gasifier. Research and development, field testing and interactions of over 25 years at IISc.
- Has been tested with natural gas engines with fitments to operate on producer gas from 1 kWe to 1000 kWe for 1000 to 30000 hours, larger ones as commercial projects supported by the IISc laboratory.
- Technology transferred to many Indian companies and Japan and GE-USA.

Varieties of plantation and agro-residues that can be used in the gasifier

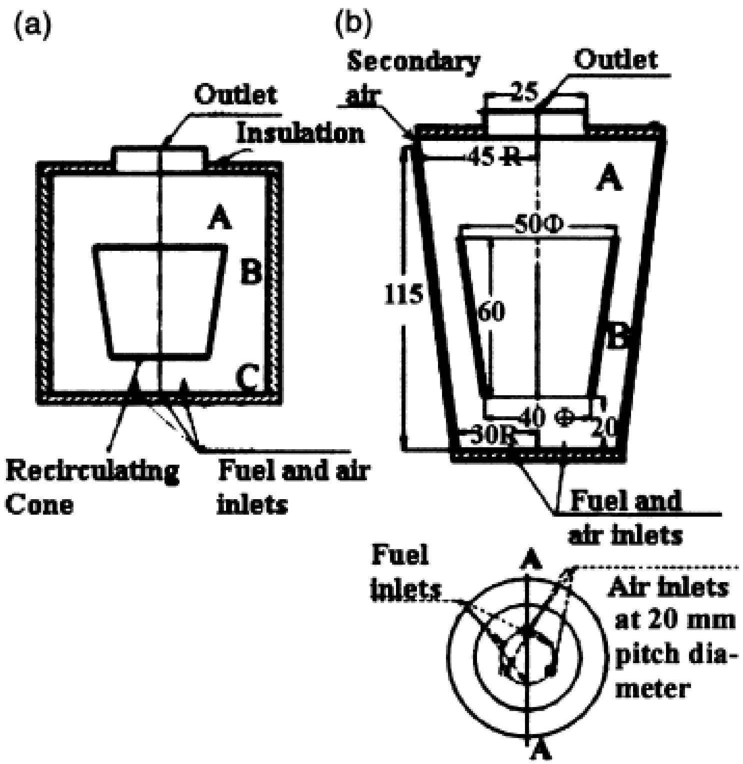
Sized wood pieces 20 to 100 mm size and briquettes from light residues

- Can these technologies also serve coal when brought down to 20 to 50 mm size?
- We must recognize that coal char is much less reactive than "charcoal".
- Research supported by DRDO on this subject is currently beginning at IISc.

New gasification technologies (2) - Coal

Combines idea of flameless combustion (or MILD combustors) with pulverized coal

MILD = Moderate or Intense Low oxygen Dilution



From Proc. Comb Institute, 30 (2005), pp 2613 – 2621, Sudarshan Kumar, PJP and HSM

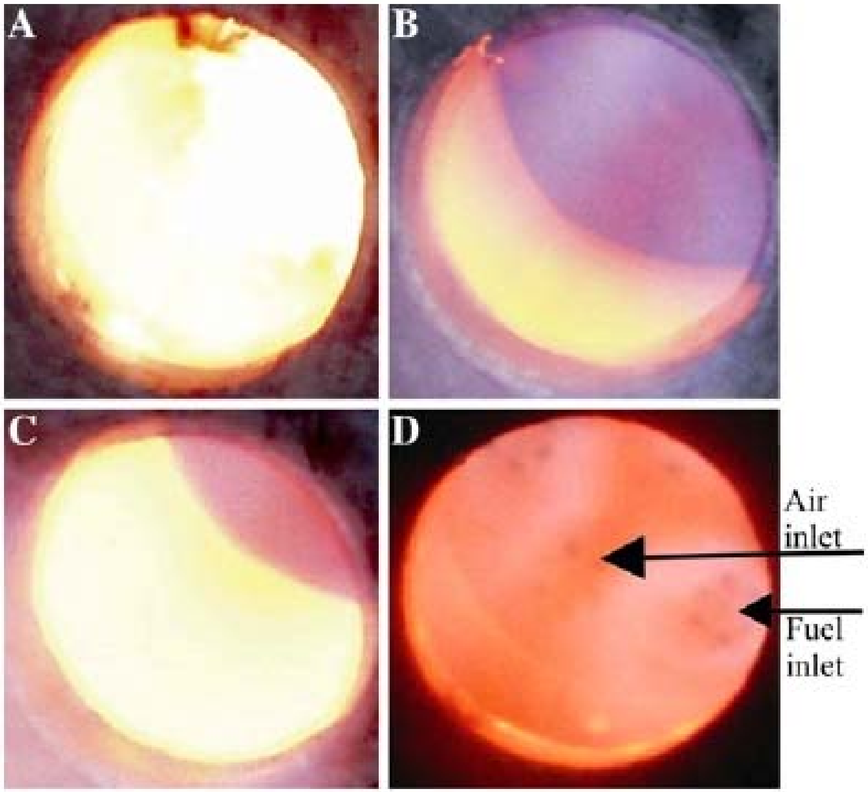


Fig. 7. Comparison between conventional and mild combustion. (A) Conventional turbulent combustion with low recirculation rates. (B,C) Mild combustion mode with LPG fuel. (D) Mild combustion mode with producer gas fuel.

From Chinese studies….

The use of coflowing jets with large velocity differences for the stabilization of low grade coal flames – 21st symposium, 1986, pp 567 - 574

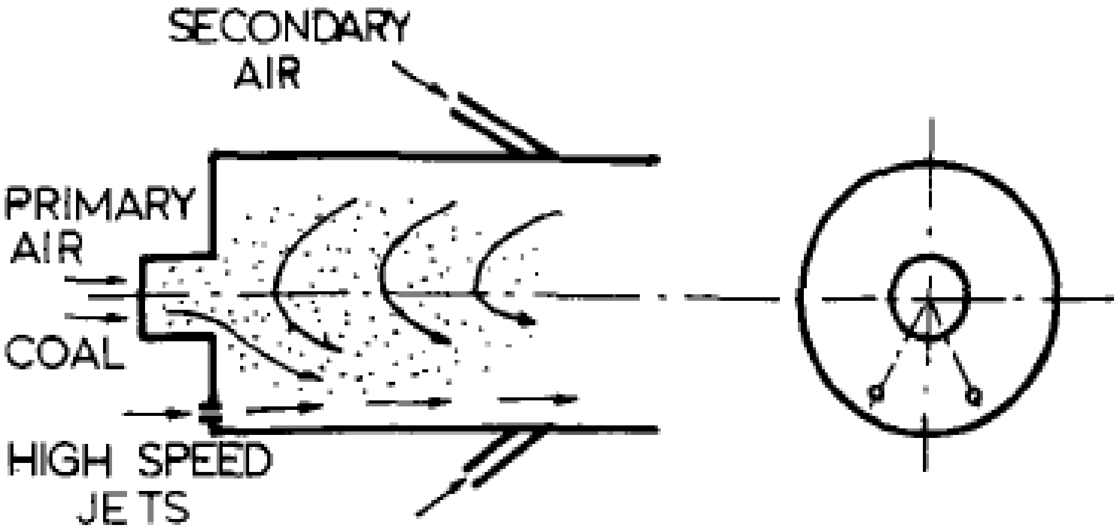


FIG. 2. Schematic diagram of the "coflowing jets with large velocity differences" principle

From Chinese studies……

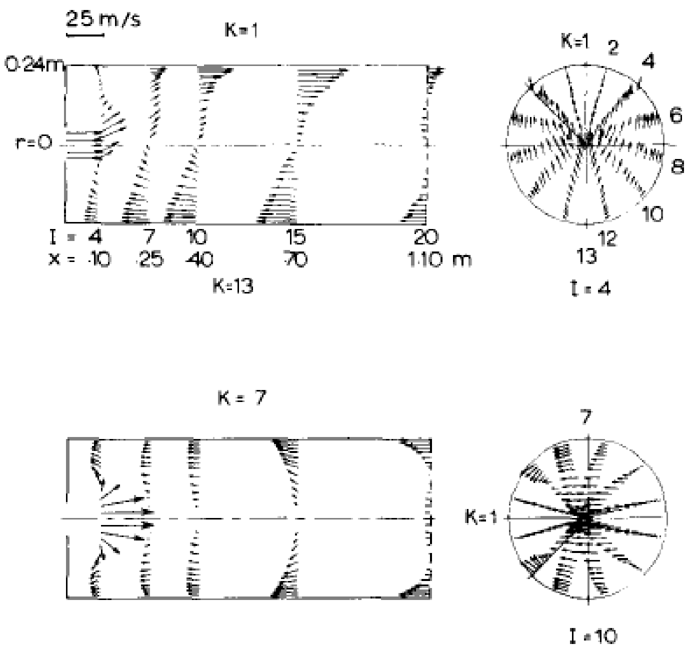


FIG. 3. Computed flowfield of a combustor using the coflowing jets (cold flow)
2 high speed jets located at $r = 0.21$m, at 45° from the vertical line (K = 4), high speed jet, velocity = 248 m/s, flow rate = 0.00486 kg/s (each hole)
primary air velocity = 25.6 m/s, flow rate = 0.238 kg/s

The benefit – No oil assist

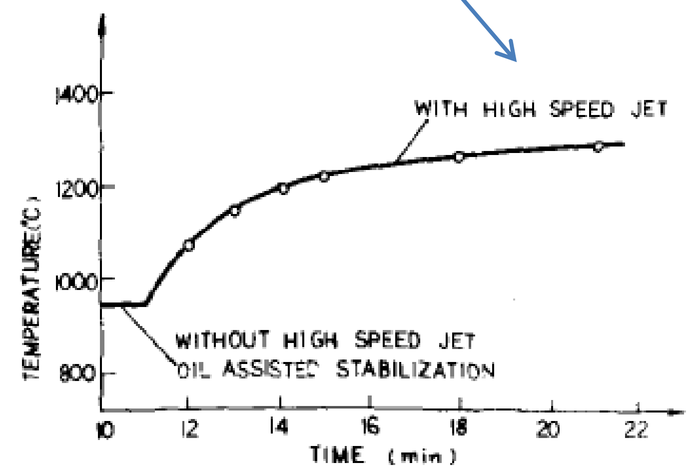


FIG. 6. Temperature rise after turning on the high speed jets, low volatile bituminous

Comment: It is clear that aerodynamics is playing an important role in the two-phase flow and heterogeneous reaction. These are studies aimed at burning poor coals. There are so many other partly symmetric geometries one can think of for the reactor.
These can be undertaken provided industry shows "interest".

Bioenergy for enhanced quality of rural life and national economic resurgence

This subject close to my heart is one on which I have spoken at many platforms, presented a case to SAC-to-Cabinet in 2005 and argued the subject at UNDP class meetings – all with little effect! (- at least hear me out, please)

Liquid biofuels - some irksome questions-1.

- GoI recently made an announcement "**India's oil import bill leaped 40 per cent to a record $140 billion in 2011-12 as high oil prices shaved off much of the nation's GDP growth rate".**
- **That it was just 20 billion USD ten years ago shows the enormity of the problem. This has now become *$ 180* billion dollars!**
- Very few who matter are concerned (PM, PM and FM) about resolution of the problem. Those who are concerned (like me, for instance and not too many, though) do not matter! …….and business as usual scenario
- Our current wealth – 30 mHa of culturable waste land (MRD-NRSA 2010 report - http://www.indiawaterportal.org/taxonomy/3/Wasteland-Mapping)
- With tropical climate and varied water resources, can't we grow high yield returning plantations of oil producing trees on these lands?
- Surely, it is not easy. Land is not fertile, there may not be enough ground water, etc, etc. And, it costs money. But…..is buying oil from overseas less expensive? – 140 to 180 billion USD/year at that.
- As of now most oil management in the country is a matter of largely trade.

Liquid biofuels - some irksome questions - 2.

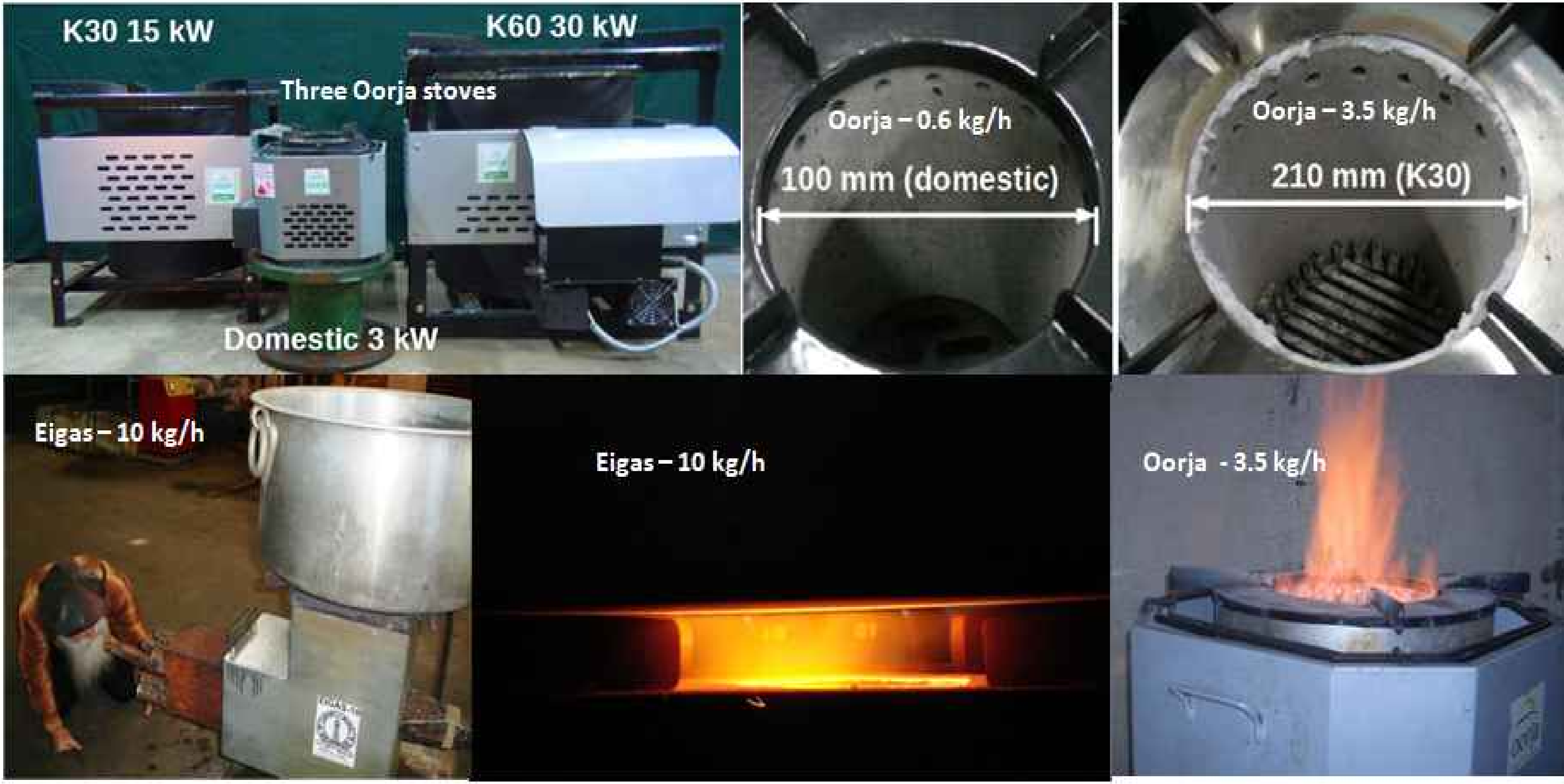
- Unless we must move into large scale production no difference to the economy can be made. This to my mind, is the single largest economic issue (compared to any discussed in the last 5 years). I am reminded of a recent talk by Gujarat CM - Modi at a college in New Delhi that unless we do things at the appropriate speed and scale, it does not make any sense.
- Has nobody else done things like greening barren lands? The answer is Israel has done fabulous things – advanced agriculture in desert regions.
- Has anybody else benefited from bio-related liquid fuels (since usually following is easier than treading new paths – as they say!)?
- The answer is Yes. Brazil, Malaysia and Indonesia have done remarkable things.
- Should we be always concerned with poor yielding Jatropha curcus (~ 1 t/ha/y)? Should we not consider Oil palms of very high yield (4 to 6 t/ha/y)? Should we be afraid of food vs. oil debate since it is there anyway with ethanol vs. sugar and true of all biogenic output?

Liquid bio-fuels – some answers

- Like Petrobraz, can the GoI should entrust IOCL and HPCL with the responsibility of increasing the fraction of bio-fuels to some meaningful value – say 40 % in five years. It is up to them to use the Governmental machinery, R & D institutions and private industry to create wealth.
- Leasing lands to a very large number of profit making private industries to grow multi-purpose plantations, of course largely oil producing, using all available knowledge in the space within or outside the country.
- Employing local labor including farmers will enhance the local employment –with each hectare accounting for at least six unskilled and skilled jobs – amounting to at least 100 million rural jobs with a monthly income!.
- Due to this reason, farmer suicides cannot occur since they get monthly salaries! Industries (with this land) have invested from their profits in returns that may take time – six to seven years. Facilitating long return time industrial investment in should be facilitated with Governmental fiscal support on taxes, etc.
- No Governmental direct grants need to flow into this sector. A number of issues related to the work force will throw up human related problems. These should not be difficult to solve either since everybody benefits – the people, the Government and the environment.
- This can be a win-win-win-win-win-win = win^6 formula

Bioresidue for cooking

- Bioresidue based cooking is widely practiced in 500 million hhs across the world using 2.5 billion tonnes of agro-residues. In some African countries, dependence of biomass is as much as 95 %. The amount of biomass used for cooking in India is comparable to the coal used for power generation (already noted).
- Large international donor agencies are involved in funding these efforts.
- They assume (incorrectly) any improved stove must function with a variety of solid bio-fuels despite variation in (a) size, (b) shape and (c) density all of which have significant influence on the efficiency and emissions.
- Surely gasoline is not the fuel for compression ignition engines and diesel not for spark ignited engines! …Why insist on good performance from unprocessed fuels?
- Good Science that has been applied to most other fields is largely missing here. It is enthusiasts field!
- Much has happened because of the use of science of gasification and elements of combustion science and involvement of industry – initially BP, energy and now FEPL.

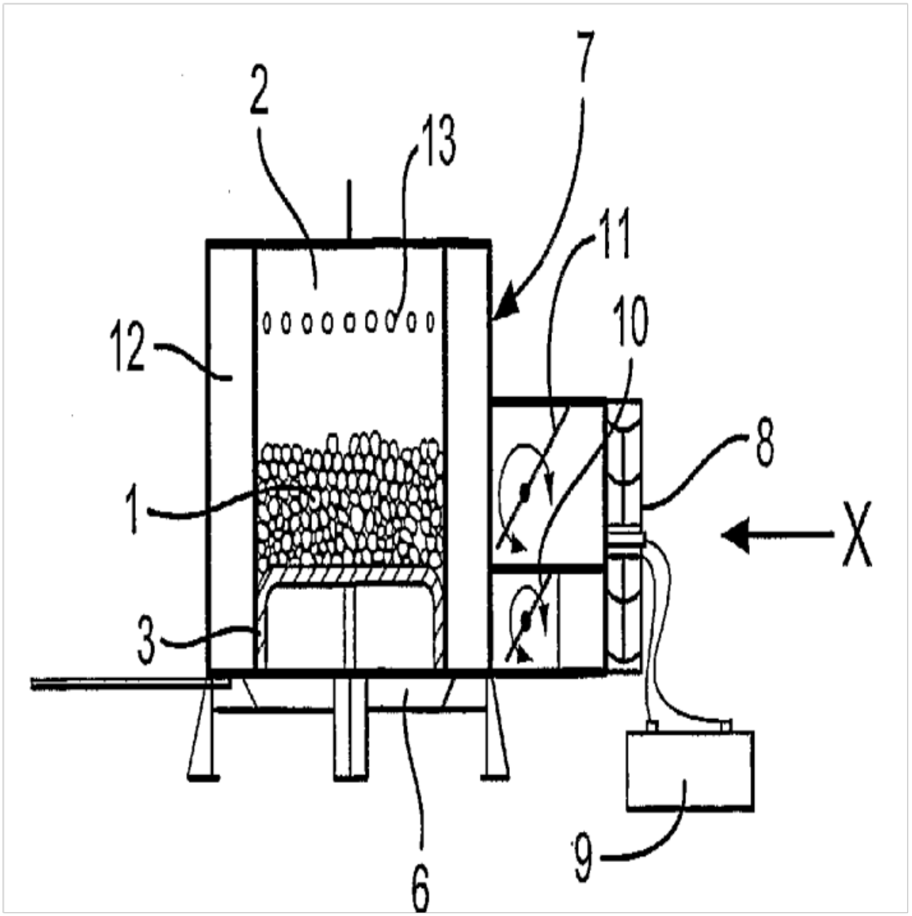


Supply fan air supply for "gasification" of prepared agro-residues based pellet fuel and then "combustion of combustible gases" in the vicinity at the correct mixture ratio – in a slightly fuel-lean condition to ensure reduced emissions.

Functions much like a "gas" stove.

1.5 W powered fan is adequate for a 3 kW thermal system. Efficiencies – 50 to 70 % much like kerosene/gas stove. $CO:CO_2$ ~ 0.012 - 0.015 << required norm

Just an aside - Simple experiments on coal in "biomass systems" To show how 28 % ash coal behaves during combustion.



The reverse downdraft gasifier stove – air for gasification from the bottom and the air for combustion from the top holes. Flame in phase II (coal char combustion) right

And So,

- Recognize that biomass is responsible for food, fuel, fiber and chemicals unlike other renewables and do not ignore it. Face debates squarely depending on rational data and not simply fears.
- Recognize that any oil produced constitutes 20 to 25 % of the biomass that the plant produces. Rest of the biomass is solid – fuel if other uses are absent.
- Create a strategy to produce solid wastes into shaped, sized dry mass in the form of pellets, briquettes or sized firewood with identification of meaningful combustion properties – density and ash content and make them available in the market like the availability of LPG/Kerosene.
- Making "good" solid fuel available allows private stove manufacturers to make a difference to the cooking solutions that are kitchen and environment friendly.
- Reduce the finance outgo from 180 billion USD to 20 billion USD in ten years… a good enough publically acceptable mandate!!.
- Remember the poor also benefit. The advanced stoves and good solid fuel will make their cooking environment very friendly.
- Small bio-power can also give them electricity that they can turn on and off as they want.

Indian engine research - the lows (?) and how to make them high

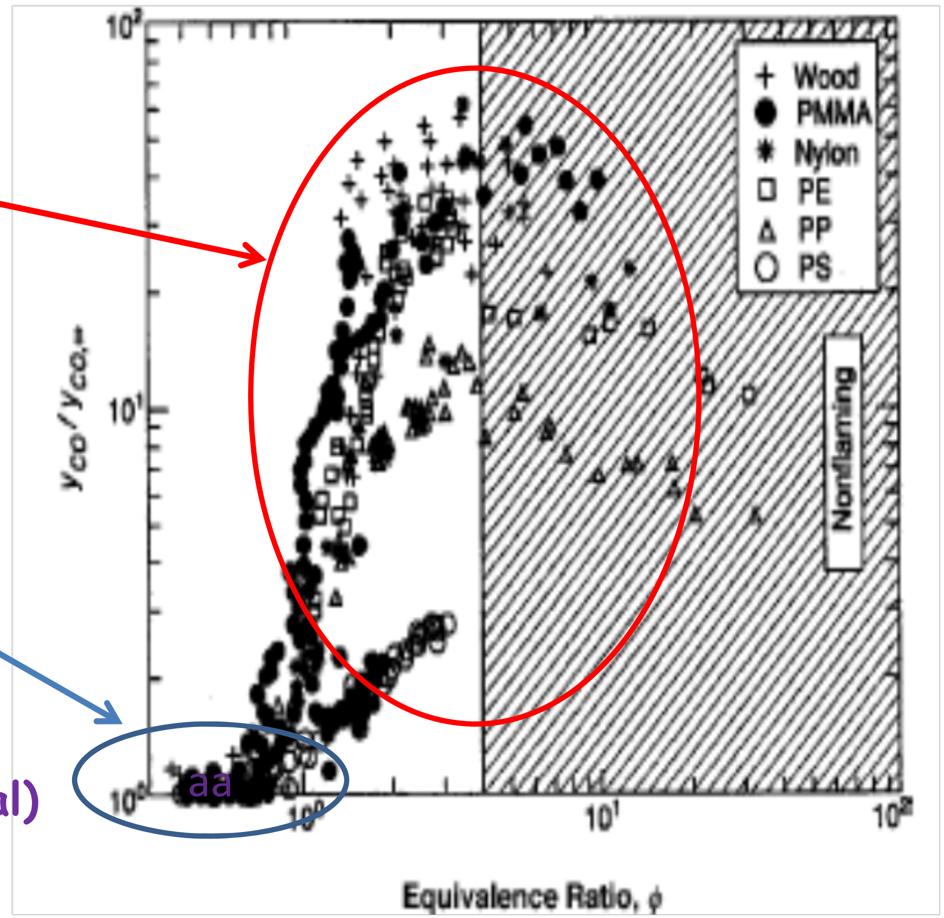
- Engine research has meant different things to different groups - For engine companies involved in producing cars, getting as much information from overseas has been the major action; For academic groups, testing different fuels under various conditions and measuring performance.
- Except minor efforts from academic groups contributing to engine development, these efforts have been going on with little intersection.
- The primary reason, I believe, is that much private money is put into R & D by companies overseas (with deep pockets) with better paid, very competent scientists with first class equipment.
- Competition demands collaboration with level-difference – very difficult to start and maintain. Making inroads into this tough environment requires infusion of special skills. These, to my mind, are in modeling skills with detailed experimental information that can be obtained from literature to start-off and create situations for deriving respect from car/truck/two-wheeler manufacturers.
- Emission predictions with complex flow simulation may be a better bet.
- This is not entirely easy and unless done, progress is difficult to achieve.

Highs (?) in Combustion science and lows in Fire science research

- Whatever be the causes, definitive working groups in classical combustion science exist at least in IITs and IISc, even if more is required. In comparison very small effort goes on with regard to Fire science....what is so special, one might ask?

Fire science domain,
Uncontrolled combustion, *$\varphi > 1$,*
CO, PAH and soot emissions significant.
Radiation controls the dynamics very much more.

Combustion science addresses largely *$\varphi \sim 1$, limiting emissions by design. Flames are clean*



Combustion scientists: Fire scientists
3000:100 (international)
100:10 (India)

Highs (?) in Combustion science and lows in Fire science research - 2

- Greater requirement is much better diffusion of information across groups missing now. In the USA, for instance, the combustion sections hold meetings where much greater diffusion occurs benefiting even the research students. This will cause indirect betterment in quality and self-calibration.
- Alternate efforts to provide special incentives for groups to meet along with research students is perhaps needed. More intensive discussions are the most needed aspect.
- Fire science is practiced much less compared to combustion research; the effort currently put in 3 to 4 places is subcritical; even the limited integration is completely missing.
- Its demand is increasing with pattern of development following the pattern of advanced countries with sensitivity to fire safety absent or nearly so.
- Creating a better recognition and support should not be postponed for far too long!

Energy and environment – new issues requiring national perspectives.

Three issues of large scale combustion of global importance that the country may be put on a back-foot in international global climate change issues are:

- Brown clouds over Asia and Africa affecting global climate
- Black carbon issues over Africa and Asia affecting climate in China?
- GHG emissions, CO_2 (1.5W/m^2), CH_4 (0.55 W/m^2), Black carbon (0.8 W/m^2) and NO_x (0.15 W/m^2)

Brown clouds…

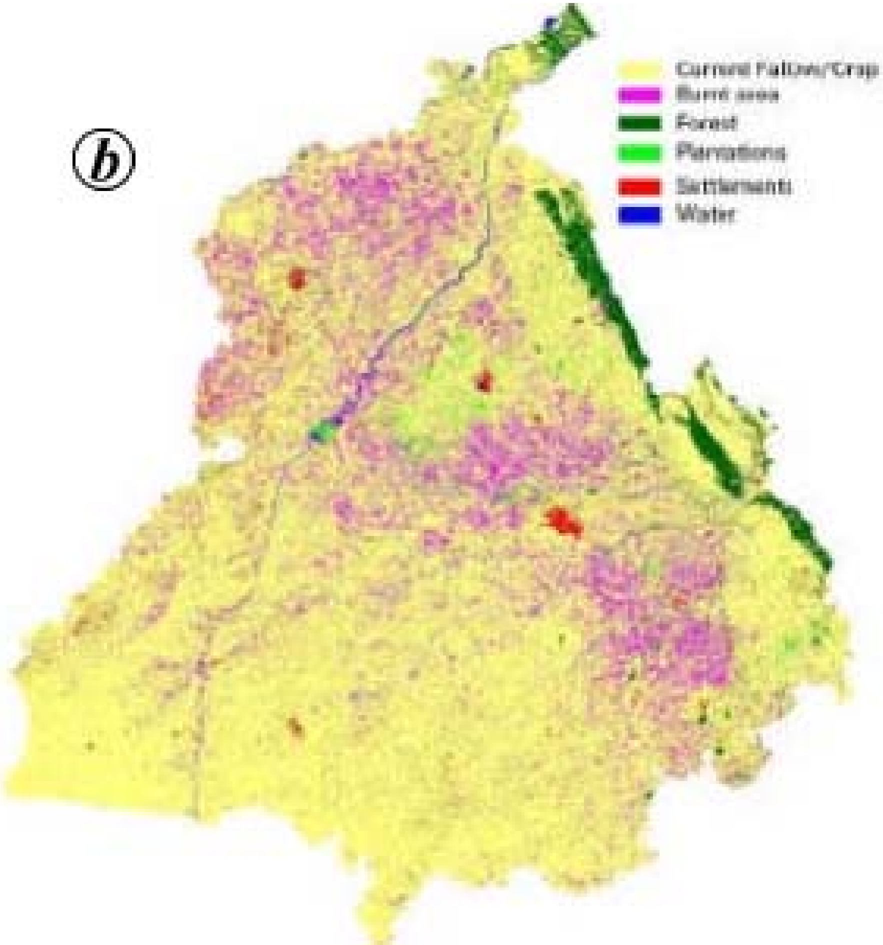
The **Indian Asian brown cloud** is a layer of air pollution that recurrently covers parts of South Asia, namely the northern Indian Ocean, India, and Pakistan.[1][2] found in the Indian Ocean every year between January and March.

The Asian brown cloud is created by a range of airborne particles and pollutants from combustion (e.g., woodfires, cars, and factories), biomass burning[4] and industrial processes with incomplete burning.[5] The cloud is associated with the winter monsoon (November/December to April) during which there is no rain to wash pollutants from the air.[6]

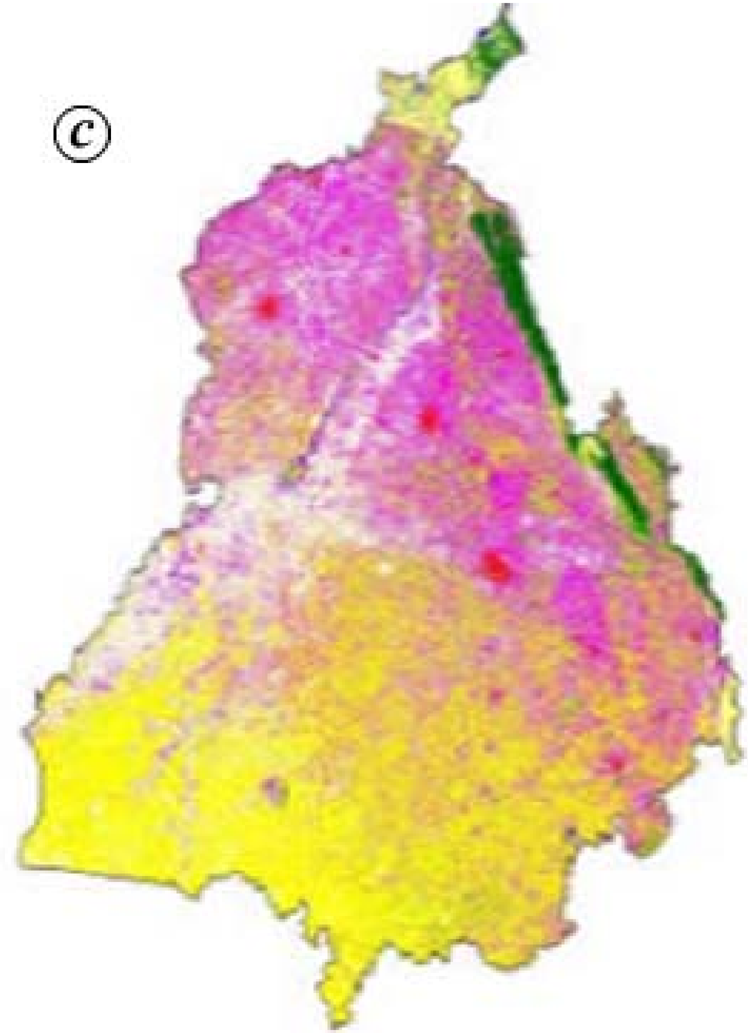
- from Wikipedia

Black carbon

- In climatology **black carbon** or **BC** is a climate forcing agent formed through the incomplete combustion of fossil fuels, biofuel, and biomass, and is emitted in both anthropogenic and naturally occurring soot.
- It consists of pure carbon in several linked forms. Black carbon warms the Earth by absorbing heat in the atmosphere and by reducing albedo, the ability to reflect sunlight, when deposited on snow and ice. Black carbon stays in the atmosphere for only several days to weeks, whereas carbon dioxide (CO_2) has an atmospheric lifetime of more than 100 years.
- Especially for the tropics, BC in soils significantly contributes to fertility as it is able to absorb important plant nutrients (also used in the form of bio-char for this purpose).
- Black carbon travels along wind currents from Asian cities and accumulates over the Tibetan Plateau and Himalayan foothills.
- Currently the focus is on biomass burning stoves in India.
- - from Wikipedia



Wheat field burning after harvest
Punjab – 5500 km^2 May 2005



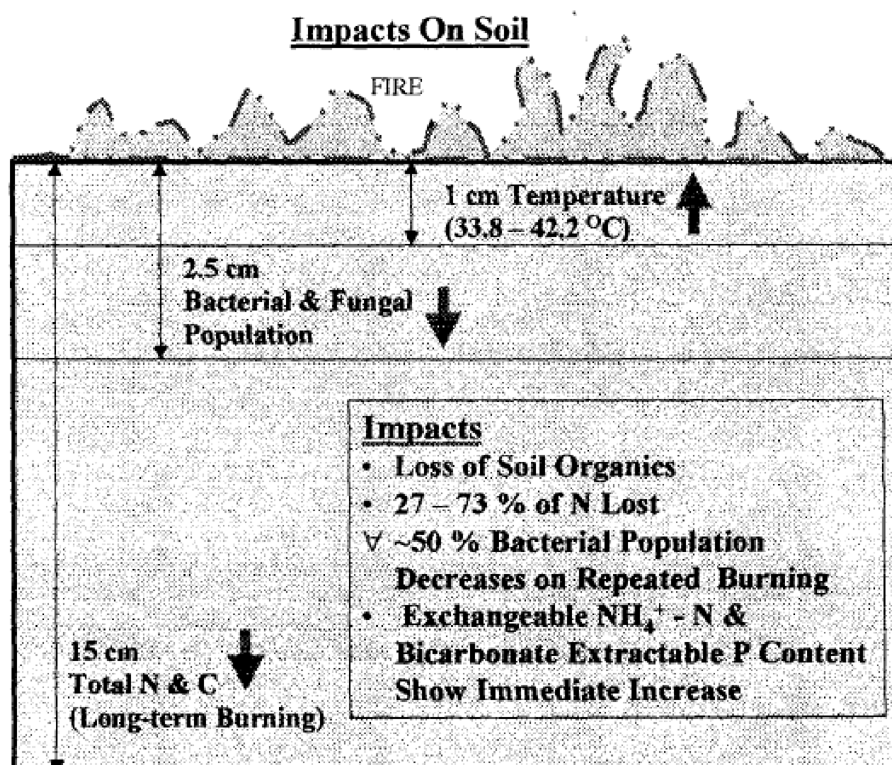
Rice field burning after harvest
Punjab – 12,600 km^2 Oct 2005

From an NRSA paper, Current Science, June 2006

Burning of Sugarcane fields – tops and leaves in most countries,
India, Brazil, Cuba, Australia….

Leads to loss of nutrients…
Claims of climate change due to these effects – aerosols, soot, ….

Solution: Can the waste left on the fields except for a minimal amount be converted to standard fuel – even if it costs quite a bit?



Therefore,

- Technologies that reduce the green house gases, black carbon must be examined and implemented nationally.
- This helps cutting down indoor air pollution that is the cause of health problems in the rural setting and reduce the emissions to the atmosphere.
- This is not an issue of any large financial subsidy – a burden to the Government.
- There are strategies that can help diffuse technologies commercially with necessary support to those below poverty line (BPL) already in place.

- The implication is a possible enhanced status in an international setting that is overcome by global climatic changes that most deep thinkers find as difficult to reverse *(Clean energy progress too slow to limit global warming, warns IEA, Guardian, 17 Apl 2013).*

General questions of significance

- Why has "Indian science" not become such that all concerned can take pride?
- Despite vociferous statements from platforms, clearly, the academia are not connected to reality to an extent that public can appreciate the connectivity. It is not the lack of communication as some people say and want to think.
- It is simply that the academia do not discuss their functional role with regard to the connectivity to reality, either science or technology in ways that there is shared understanding even if there are differences (I am reminded of the complete lack of the most elevating "dialogues of Socrates and Plato").
- The intense cauldron effect in achieving individual dependent scientific goals has not taken place – I would say, has not been even recognized as a pathway.
- Some inferences of this class can be gleaned from "you and your research" by Richard Hamming, 1995 (google search gets you this article)
- Based on PM's observations at the Indian Science Congress (Jan 2013), DST has created a document "Science, Technology and Innovation policy" and allowed it to be discussed by the Academies……….and from what I know, little conceptual progress has occurred.
- I guess these are matters for all to think, debate and take measures.

…………………………Thanks for your attention