SOLAR STILL FOR ROSE WATER PRODUCTION

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This paper is the outcome of students' project work guided by the author. An attempt has been made to design and develop a solar still for rose water production in India. This unit has the following features : i) possibility of tilt adjustments to suit the different altitudes of Sun, ii) specially designed stepped basin for conveniently keeping the rose petals and water in an inclined position and iii) cover which can be opened to facilitate the cleaning operations. This unit supplied 3.7 litres of rose water in three days during winter in Madras, in India. The sunshine and solar radiation particulars of Botswana are shown to indicate that a better climatic conditions prevail here for a higher production rate.

1. INTRODUCTION

The simplest and widely adopted method for rose water production is the distillation process. In this process, rose petals are boiled with water using thermal energy and the generated steam is condensed as final product. The thermal energy is normally supplied by using kerosene stove, gas burning or by an electric heater. However, increasing cost of fast depleting fossil fuel resources and frequent breakdown of heating filament in electrical appliance are the main factors which resort for an alternative. In this context one has to remember that solar energy is abundant in Botswana and rose plants are cultivated all over and therefore, utilisation of solar energy looks an attractive method for the production of rose water. It is necessary to mention here that rose water is very good for skin care and used as cosmetics. Diluted rose syrup is good for health as cool drinks.

2. SUNSHINE AND SOLAR RADIATION IN BOTSWANA.

The duration of bright sunshine is recorded at all the nine synoptic stations in Botswana, which are equipped with the Camball-Stokes sunshine recorders. Table I shows the highest, lowest and annual mean hours of bright sunshine. The lower figures, in bracket, indicate bright sunshine duration as percentage of the day-length. The day-length is to be taken as the time during which the centre of sun is above the horizon. Table 2, (Bhalotra Y.P.R[3]) shows the calculated average daily total solar radiation on horizontal surfaces. General observation can be made from this table that the values of solar radiation in Botswana, is generally highest in December (23~27 $MJm^{-2}day^{-1}$) and lowest in June (14~17 $MJm^{-2}day^{-1}$) .

We have earlier worked on the design of small and efficient stepped basin type solar still for the production of distilled water for our laboratories at Madras, India (Latitude 13.4°, longitude 83°). In order to enhance the productivity during the winter months and when the Sun is at lower altitudes, multi-basin , tilted type solar still was later developed.

As a project for the students, we slightly modified this solar still during 1992 for the production of rose water, where additional facilities were provided to feed the device with rose petals and also facilities to remove the rose pulp remaining after boiling. This waste pulp mixed with soil can be used as fertiliser. The design details and performance of this device is reported in this paper.

3. DESIGN PARTICULARS

The solar still (figure 1) consists of a wooden box of outer dimensions 1005 mm x 210 mm x 230 mm having a top door that can be opened out side . The door consists of a frame with glass cover of area, 0.6 m^2. Three aluminium trays each having basin area, 950 mm x 140 mm made from 20 gauge aluminium sheet are fixed in stepped fashion inside the wooden box. The height of each tray is t60 mm at rear side and 27 mm at the front. Fibre glass insulation is provided at the base of the trays. For collecting the distillate, an aluminium channel is provided at the bottom. An adjustable M.S angle iron stand is provided to change the inclination of the solar still from 3° to 45° from horizontal with an idea of utilising the maximum solar radiation throughout the year. The still is made leak proof by providing rubber gasket beneath the wooden frame of the openable door. The details of the design is given in figure 2.

4. PERFORMANCE

The performance of this solar still was carried out in the spring season, September 1992 in Madras, India. The unit was oriented due south-east in alignment with Sun's transit and its inclination was adjusted to maximum tilt i.e., 45° to the horizontal. Rose flowers, 2 kg of mass mixed with 7.2 kg of water was fed into the three trays equally distributed. The rose water output was measured daily. During the production, the solar radiation on the glass plane of the still was recorded by a pyronometer coupled with an integrator. The performance readings are shown in the table 3.

The efficiency of the solar still was calculated by using the Angstrom formula, $\eta = \dfrac{243 \times M}{R}$, where

η = the percentage efficiency of the solar still,

M = the quantity of rose water collected in $kg.m^{-2} day^{-1}$.

R = total solar radiation on the glass plane in $MJ.m^{-2}day^{-1}$.

Considering the first reading from the table 3, the rose water collected on 15 Sept.

$$M = \frac{1.385}{1000x0.6} = 2.31x10^{-3} \quad kg.m^{-2}day^{-1}.$$

Solar radiation, R = 24.57 $MJ.m^{-2}day^{-1}$.

$$\text{Hence, } \eta = \left(\frac{243x2.31x10^{-3}}{24.57}\right)x100 = 22.84\%.$$

From the readings shown in table 3, it is clear that under local conditions the multi-basin tilted solar still supplies 3.662 litres of rose water in one feeding for three days during the spring season and 21.4 % efficient

5. COST ANALYSIS

The materials for fabrication of this solar still are aluminium sheet to make trays, wood, fibre glass insulation, plain glass, mild sheet angle etc. The cost production of this unit workout approximately P 80/- only. The monthly production of rose water is about 37 to 40 litres and it may be more during summer. Considering the cost of rose water in the local market at P 15 per litre, it can be estimated that this device gives an output of rose water worth of P 370/- per unit. If we consider the cost of rose flower petals at P3/- per kg. the cost of roses per month will be P 30/- for ten trials. It is therefore, clear from the above stated estimate the money pay back period of this unit is less than a month.

6. CONCLUSIONS

- The multi-basin, tilted type Solar still is suitable for rose water production in the rural areas and this programme can be included as one of the small scale industries developments of Botswana.
- The efficiency of Solar still is 21.4 % and the input is abundantly available Solar Power.
- The money pay back period of one unit is less than a month.
- The solar still explained in this paper can be easily and successfully fabricated at the cheapest cost
- No extra power is required to heat and boil the rose water.
- No extra power or fuel is required for condensing the rose water vapour.

The solar still is simple to fabricate and it will operate for long period with little attentions

7. REFERENCES

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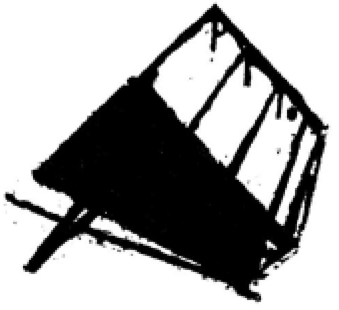

FIG. 1 SOLAR STILL FOR ROSE WATER PRODUCTION

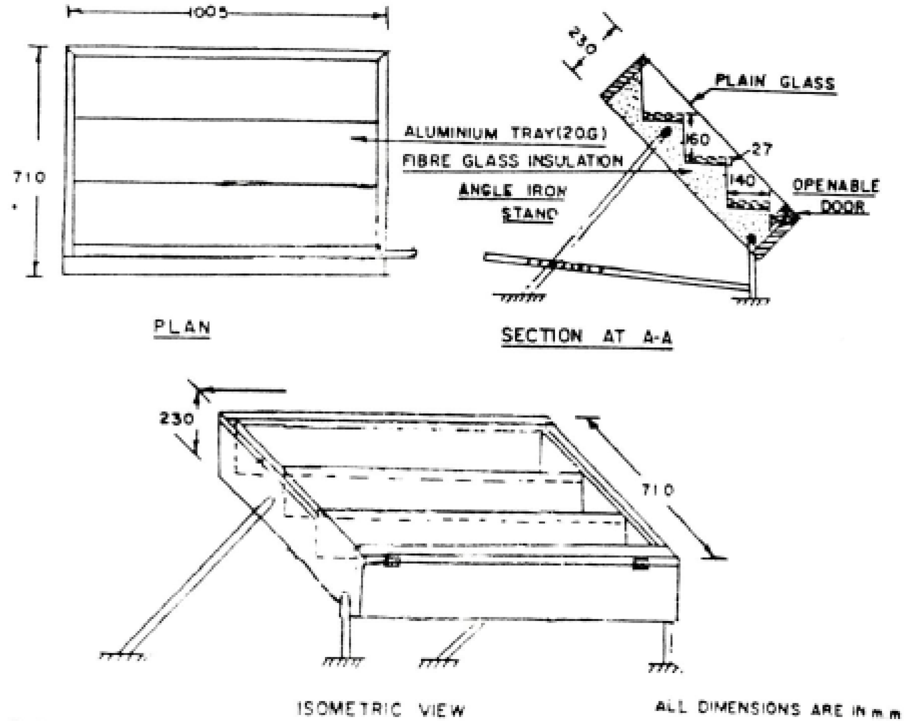

FIG 2 DESIGN DETAILS OF SOLAR STILL FOR ROSE WATER PRODUCTION

Table 1 Solar power potential of Botswana. Hours of bright sunshine.

Station	Lowest	Mean	Highest
Gaborone	8.3 April (67)	9.0 (75)	9.9 Aug. (88)
Mahalapye	7.9 March (65)	8.5 (71)	9.2 Aug (82)
Kasane	6.2 Dec (47)	8.2 (68)	10.0 Sept. (84)
Francis Town	7.5 Dec. (56)	8.7 (73)	9.9 Aug. (88)
Maun	7.5 Feb. (60)	8.9 (74)	10.2 Aug. (90)
Shakawe	7.1 Jan. (55)	8.6 (72)	10.1 Sept. (85)
Ghanzi	8.2 Jan. (62)	9.2 (77)	10.4 Aug. (92)
Tshane	8.5 Feb. (66)	9.4 (78)	9.9 Aug. (88)
Tsabong	8.8 May (82)	9.7 (81)	10.6 Dec. (78)

Table 2 Calculated average daily total solar radiation on horizontal surfaces in $MJm^{-2}day^{-1}$

Station	Lowest	Mean	Highest
Gaborone	14.6 June	21.1	26.2 Dec.
Mahalapye	16.2 July	20.7	24.7 Dec.
Francis town	16.1 June	21.3	24.1 Jan.
Kasane	16.8 June	20.8	23.9 Sept.
Maun	17.0 June	21.7	23.7 Jan.
Shakawe	17.4 June	21.3	24.0 Sept.
Ghanzi	15.9 June	21.8	24.9 Nov.
Tshane	15.3 June	21.8	26.9 Nov.
Tsabong	14.3 June	22.0	28.4 Dec.
Sebele	14.5 June	19.6	25.5 Dec.

Table 3 Daily output of rose water from the solar still of glass area 0.6 m^2.

Date	rose water output Litres per day	solar radiation on the glass plane $MJ\ m^{-2}\ day^{-1}$	efficiency of the solar still, %
15 Sept	1.385	24.570	22.8
16 Sept	1.202	24.738	19.7
17 Sept	1.075	20.160	21.6

CHALLENGES OF CIVIL AND MECHANICAL ENGINEERING IN THE 21^{ST} CENTURY

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The traditional societies developed facilities such as dams, wind mills, irrigation canals etc. by taking full cognizance of the environment in which they lived. Experts in the development of these facilities acquired their knowledge through experience and developed the facilities in consultation with the members of the community in order to meet their actual needs.

Over the years, however, commercialization, politics and short-sightedness have changed the ways in which these facilities were developed. Today, it is common to find mega water dams which have not only submerged large tracts of fertile land during their construction but are also a constant threat to the environment and the people living nearby.

This paper argues that the mechanical and civil engineers of the 21st century should take the relevant lessons from the traditional societies use the modern technology in mini-projects based on the natural resources such as solar, water and wind power at the local level. To achieve this, the paper suggests that, the engineers must take a greater in political discussions at all levels and learn how to mobilize finances to fund and run these facilities.

1. INTRODUCTION

About 2500 years ago, Confucius is said to have written, "study the past, if you would divine the future". This paper will do just about that: it will look into the major contributions of civil and mechanical engineers during the pre-industrial era, the role played by the same today, and from this map up possible areas for future contributions. It is self evident that, in the normal course of events, in engineering design, the designer starts his/her quest with a good look at the present and the past. The engineer then seeks a method of improving on past and present practice, and this is the first step in the process of moving forward to a new solution.

The first invention that freed man from the vagaries of nature, is the ability to make and control fire. The fire was put to several social, economical and technological uses, the most important being extraction of copper and iron from their ores, and subsequently working them into tools, weapons and ornaments. This enabled replacement of wooden and stone tools with stronger and more durable ones, including the harrow, which revolutionized agriculture. The introduction of metallurgy, whether of bronze or iron, and its processes did become the start of a way of living in which specialization and the division of labour were important factors [1]. Metal workers were a class of specialists who needed specialist equipment and who depended for their sustenance on the labours of their fellow men and women, the farming community for whom they provided the tools. Hence the beginning of a class of engineers (designers and manufacturers of engineering tools).

The high demand of tools required power sources other then human lungs and the blowpipe to produce adequate high temperature for smelting. At the same time, sufficient quantities of ores were not to be found at one location. At first, these were supplied by pack animals from distant deposits, but as larger quantities were required from more distant places, other modes of transport become necessary. The invention of wind-mill and water-mill provided solutions to both problems: the wind-mill utilized wind power to drive its rotating sails and the resulting energy was used in smelting and other activities. The water-mill worked in the same principle as the wind mill, but with the sails inverted and powered by running water. Further power requirements in agriculture, textile production, construction, military applications and transportation led to the invention of the steam-engine. With the steam-engine it was possible to drive a number of machines at one place at the same time and this arrangement was easily placed under one roof, hence the beginning of factory system. The steam engine also revolutionized methods of transportation with the development of steam locomotive and steam-ship.

The internal combustion engine, petrol or oil fueled effectively ended the supremacy of the steam locomotive for long-distance transport, as well as contributing towards marine propulsion and other applications. However, a motor car is of little use unless there are good roads to run it on. This necessitated establishment of improved roads, which culminated in permanently surfaced roads. The internal combustion engines also found application in air travel where they run airplanes, which have undergone tremendous improvements during the recent years. The invention of the internal combustion engine was closely followed by the invention of electricity and later electronics which have enabled power on tap and several control systems which work hand in hand with civil and mechanical engineering facilities.

Against this background, this paper discusses the development of civil and mechanical engineering and suggests the direction in which it has to move in future.

2. ENGINEERING IN THE PRE-INDUSTRIAL ERA

Engineering, originally meant military engineering, and it was not until the end of the 18th Century that non-military engineering, or what became known as Civil Engineering was recognized. Civil engineering is a form of human activity that has been pursued as long as human beings have sought to change the natural environment for their own benefit. A definition given for civil engineering in 1828 when the British Institution of Civil Engineers was applying for its charter states:

> "... is the art of directing the great sources of power in Nature for the use and conveniences of man, as the means of production and of traffic in States both for external and internal trade, as applied in the construction of roads, bridges, aqueducts, canals, river navigation and docks for internal intercourse and exchange; and in the construction of ports, harbours, moles, breakwaters and lighthouses, and in the art of navigation by artificial power for purposes of commerce; and in the construction and adaptation of machinery, and in the drainage of cities and towns".

Although essentially a practical profession, civil engineering is founded on applied science, and training is based on the appropriate courses in engineering as well as in ecology and public health. However, in the pre-industrial era, there often was no clear line between a scientist and an engineer as wise men worked in both fields. For example, it is clear that the astronomer, the man who looks through the telescope, is a scientist. On the other hand, the scientific instrument maker, the man who made the telescope, is an engineer. In some cases, like that of Galileo and Sir William Herschel, they may be one and the same man. Moreover, these engineers were influenced by the intellectual and artistic movement of the time. Some of them began as engineers, others were artists, while the majority during the Renaissance began as artists, but rapidly surpassed their early training and their engineering profession in an attempt ultimately to achieve a universal vision of the world.

Towards the end of the Renaissance, the unity of knowledge was once again compromised because more thorough research demanded specialization. Thus the artist confined himself to art, while the union of science and technology was maintained at least temporarily. The engineers/technicians, however, had thereby gained a breadth of outlook which they had hitherto completely lacked. This wider viewpoint was later able to benefit from the scientific progress in whose birth it had played perhaps the dominant role. The technical treatises that continued this movement which had culminated with Leonardo da Vince, were now limited to well defined techniques: Georgius Agricola's work on mines and metallurgy is the best example.

Basically, military problems, the quest for mechanization and means of transport of bulky materials were the driving forces behind most of the engineering activities during this period. Hydraulic problems such as controlling of levels of rivers and canals for opening of navigable waters and irrigation schemes constituted another force behind engineering activities. As military problems were solved separately in subsequent years, only transportation and the quest for mechanization will be reviewed in this paper.

2.1 Transportation

Universally, the transport of burdens has been by humans using nothing more than a simple devise to distribute or adjust the load to the anatomy of the carrier. Chinese coolies continue to employ, as they have for many centuries, the shoulder pole, from either end of which half the load is suspended, making it possible for them to transport many kinds of loads. Sometimes the nature of the terrain imposed conditions that were too rough, precipitous, or narrow to be negotiated by any other means than human carriers. However, the problem is that men cannot individually, carry as much as a big cart or wagon. But a wagon and animals harnessed to it need a prepared trail or roadway sufficiently wide to accommodate them and free of disrupting encumbrances.

The problem of transporting heavy loads was partially solved through the use of domesticated animals, either as haulers or as carriers. In hauling, loads were positioned in or on some sort of conveyance rather than carried on the animals' backs [2]. This required the design and construction of appropriate vehicles (wheeled or wheelless) on which to pile loads and of harnesses, especially collars or yokes, to allow the animals to exert their full strength without danger of

strangulation [3]. Both these considerations occupied the minds of the pre-industrial engineers for many generations until a reasonable solution was worked out. The engineers must have used their knowledge of infrastructure development and machines to achieve such a feat.
To facilitate transportation of bulky materials overland, it became necessary for the engineers to establish and maintain a network of roads through which wheeled vehicles carrying heavy loads and drawn by animals could travel in all weather [4]. The Romans established, maintained and administered an extensive system of stone-paved roads, said to have covered some fifty thousand miles and to have included permanent stone bridges spanning at least the smaller rivers. On the other side of the world the Road of the Incas, a most astonishing engineering feat dating back to AD 900, was constructed for some three thousand miles along the western slopes of the Andes: it was stone-surfaced with excellent bridges [5].

In some situations, land travel for bulky and constant convoys of goods was largely thwarted by towering and precipitous cliffs and all the hazards and difficulties of mountainous terrain. Here, the engineers made use of the advantages offered by water transport for which its relative speed compared to overland transit was higher considering the general inadequacy or lack of roads in the past. Also, very heavy or bulky cargoes could be conveyed by water much more easily and relatively safe from injury, loads that if consigned to all the difficulties and arduous labor of overland transit, would require an inordinate expenditure of manpower. The engineers came up with development and fabrication of several types of water based-vessels, small and large [6].

The marine traffic resulting from the use of these vessels required harbors and roadsteads to protect them during storms and when they were being repaired and refitted as well as to provide calm waters for loading and unloading their holds. The engineers came up with a skillful construction which could break the waves and yet not permit gradual silting up or the formation of bars. Hamlin [7] narrates of Pozzuoli on the Bay of Naples, where the breakwater, instead of being solid, is arched to allow the current to sweep through, and the harbour is lined by a mole with two sets of arches - the piers of the inner set being set opposite the opening of the outer set, in order to break the force of the beating waves.

To extend the possibility of using water based vessels inland, the engineers constructed man-made waterways (canals) which were coordinated with nearby streams, rivers and lakes. Although the waterways took advantage of the natural water bodies large portions of canals had to be dug, into which water had to be tapped from adjacent streams which had in turn been dammed to impound the water. To do this the engineers constructed sluice gates and lock mechanisms to effect the damming of the water [8]. They also constructed permanent bridges across the canals to accommodate pedestrians and land-based traffic.

2.2 Mechanization in the pre-industrial era

The quest for mechanization began with a search for prime-movers, the machines that provide motive power for other tools and machinery by converting the power of animal muscles, running water, wind or heat into a convenient form of mechanical energy. The introduction of a new prime-mover generally renders energy available in a more concentrated form, and permits a new level of production.

During almost the whole of antiquity the only prime-movers were men and animals. At first, men had muscle power only. Generally in antiquity the state had at its disposal concentration of man-power, in the form of statute-labour or slaves for the construction of great public works or the erection of monuments. Concentration of energy was obtained by the use of large gangs. Massive machines such as the cranes used in architecture, and water-wheels for draining mines, were worked by men or by animals. The tread-mill was often employed in machines for converting muscle-power into rotary motion. Gangs of soldiers or galley-slaves provided motive power for ships, and for constructing roads and aqueducts [1]. It was difficult to replace human labour with harnessed animals more extensively mainly because of ignorance of animal anatomy at the time. In applying the ox-harness to the donkey and horse the ancients robbed these animals of most of their natural power. Though the horse when used as a pack-animal could carry four times as much as man, the harness prevented it, when used for draught, from exerting more than part of its available strength [9]. Subsequently, the engineers of the time designed the collar-harness, enabling the horse to displace the ox in drawing ploughs and farming equipment.

Lack of suitable harness for draught-animals and of proper method to protect the hoofs of the animals, left the ancient world with man as the main prime-mover until the advent of the water-mill. These mills were for the grinding of corn - a constantly recurring burden in every ancient household, and one that provided a particularly strong incentive to mechanize the corn-mill. The most primitive water-mill was designed by Greek engineers and was often referred to as the Norse mill, in which a vertical shaft or axle bore at its lower end a small horizontal "wheel" composed of a number of scoops. The shaft passed upwards through the lower mill-stone and was fixed to the upper stone by a cross-bar spanning the aperture or "eye" of the stone. Such a mill is also called the horizontal water mill and requires a running stream to work satisfactorily [10].

The Greek mill, though mechanizing domestic corn milling, would have had little effect had it not inspired a Roman engineer of the first century BC to construct the more efficient vertical or Vitruvian mill. Using his knowledge of rudimentary gear-wheels and other mechanical skills, the inventor transformed the old Greek mill into a much more useful machine, with the water-wheel placed in a vertical position [11]. The Vitruvian had output of energy which was much higher than that of any machine driven by man or beast, and indeed of any other power-resource of antiquity. Once it was realized that the water-mill could not only grind corn but supply power to other machines, possibilities of technological operations at a new level were disclosed. Soon the corn-mill was followed by industrial mills such as stamping mills for crushing ore and hammer-mills, fulling-mills, tanning-mills, paint-mills and saw-mills. Subsequently, water power became the basis of mining and metallurgy. The use of the water-mill in industry encouraged the improvement of gearing, and of practical mechanics generally as shown in the Engineer's handbooks of the early sixteenth century [12]. Transport was also made easier, as cities and industries tended to grow where there was running water and therefore a supply of energy.

In the regions where there was no water but where steady winds prevailed, the engineers adopted the Vitruvian to be driven by wind instead of water. This necessitated inverting the mechanical arrangement of the Vitruvian mill; that is, down from the sails rather than up from the water-wheel. In some other places such as China the wind-mill was developed independent of knowledge of the Vitruvian mill. By the early thirteenth century the windmill became the typical prime-mover primarily used for water-lifting or pumping machinery [13]. The water-mill and wind-mill dominated technology until the end of the eighteenth century, and their capacity which was constantly improved by the engineers of the time, determined the range of machinery, processes, and products used during that period.

Dependency on water-mills as a power source meant that industries had to be constructed near fast flowing rivers or streams where this source of power was available. This inspired the engineers of that time to search for other sources of power to reduce reliance on streams. The search led to the introduction of the steam-engine by Thomas NewComen in 1712 for pumping water out of mines. James Watt was responsible for developing the double acting steam-engine and for introducing the condenser that greatly improved the engine's thermodynamic efficiency and also the first rotative engines [14]. This marked the beginning of the industrial revolution which ushered in many machines powered by the steam-engine. Steam-engines were developed for powering pumping stations, factories, ships, traction vehicles and the first electric generators. With the steam-engine as the power source, factory masters could now huddle factories together check by jowl as close as was convenient to them. Passenger transport being non-existent for all but the wealthy, the workers had to give up the freedom of the countryside and move to houses within walking distance of the factories, houses often rented to them by their masters. This was the beginning of the current problem of rural-urban migration with its repercussions. Subsequently, steam locomotives were introduced which revolutionized traveling and transportation of bulky materials.

3. ENGINEERING IN THE PRESENT ERA

The present era can be said to have begun with the outset of industrial revolution, but was highlighted in 1847 when a group of engineers, who felt that the Institution of Civil Engineers was uninterested in the new breed of engineers resulting from the development of railways and formed the Institution of Mechanical Engineers in Britain. Other countries followed suit, although not immediately.

In the development of prime-movers, the mechanical engineers invented the steam turbine in the late 19th century which largely replaced the steam-engine in most applications. Coal was used to fire the boilers for raising steam and it was increasingly replaced by oil. Again, this was the beginning of another problem, the emission of harmful gases into the atmosphere whose effects are becoming evident today. With increasing scarcity of oil, nuclear power for electrical-power generation partially replaced other sources of power as from 1957. The unfriendliness of unclear plants to the environment is well documented [15] .

The steam-engine was used for steam-traction engines and some early automobiles, but is was replaced by the more convenient and compact internal-combustion engine pioneered by Marens, Daimler and Benz, that remains that main power plant for automobiles [16]. The internal-combustion engine was also developed for aircraft propulsion but was replaced by gas-turbine jet engine in large aircraft's. Diesel-engine was also developed by the engineers of the present era and is still being used extensively for bus and truck engines, ship propulsion, standby power generation and also for automobile engines [17].

The advent of these prime-movers paved the way for tremendous industrial activity that we are witnessing today in textiles, metalworking, agriculture and a multitude of other activities and processes that are essential to an industrial economy. Civil Engineering has also made tremendous leaps in highway construction, airports, habour and other offshore facilities, dams, railways, bridges, tunnels, complex buildings and other infrastructural facilities which have made movement both easy and safe [18, 19, 20].

In spite of all these achievements, the present civil and mechanical engineering practice has brought about certain issues which have negative impact on people and the environment. One of these issues is large hydro-electronic power plants and other gigantic dams which have submerged fertile agricultural land and pose danger to both human life and the environment. Another important issue is the restriction of important amenities such as electricity, telephones, water supply etc. to urban centres which has caused migration of people from the rural areas to these centres. This has resulted in overcrowding and acute scarcity of housing in urban centres while ample space remains available in the rural areas. The current industrial activity, both manufacturing and construction is causing untold damage to the environment [21]. While the manufacturing industry is releasing dangerous emissions to the atmosphere, the construction industry is forming large wounds in the landscape through quarrying earth and rock used in construction as well as posing a threat to forests from where wood products are derived. Yet another negative issue of the present era engineering practice is military research and development of military hardware that continues to draw large chunks of national budgets and make mass destruction equipment available. The results of wars facilitated by these equipment are loss of life, disruption of economic activities in the countries concerned and a large number of refugees all over the world. All in all, today, the engineers are only implementors of decisions made somewhere else by other parties which in most cases have no engineering background. They are also involved in the projects too late, such that their opinion, can not be implemented if it happens to be contrary to what has been decided [22].

4. ENGINEERING PRACTICE IN THE 21ST CENTURY

One of the most important lessons from the past is the development of mini-and micro-projects instead of super large ones such as water dams which have caused untold damage. The benefits of this lesson include the ability to construct these projects at several sites and hence enable the local people to remain in those sites instead of migrating to urban centres which are usually served by the large projects. There will also be a reduction in the environmental impact associated with large projects such as dams. It will also be possible for individuals or small enterprises to own and run such projects as the capital required for their development is in the whole manageable by individuals.

Another lesson which should be learnt from the past is the development of prime-movers from renewable natural resources such as water, wind and solar power. Hydropower already supplies more than one-fifth of the world's electricity but engineers need to develop efficient mini-and micro-hydropower plants so that they can serve small rural communities which are far from the main grid and yet within reach of suitable streams. Solar thermal plants are already under intensive research and this offers universal possibilities as sun rays reach most parts of the world. In conjunction with this, means of storing and transporting this power which is currently provided by hydrogen and the flywheel need to be strengthened. Wind power as a prime-mover is another lesson which should be learned from the past. Winds are prevalent in most parts of the world and are local in nature. The engineers of the 21st century should explore economic and effective ways to exploit the wind power and more importantly, effective means to store such power for use when the wind is not blowing. Besides giving a clean source of power, it meets the criteria of mini- or micro-scale which will serve the local communities and can be developed and owned by individuals/small enterprises.

Housing scarcity has been and will likely remain acute into the 21st century. The engineers need to design and manufacture houses using the breakthroughs already made in the manufacturing industry. Although this is already underway in the form of industrialized housing construction, the systems needs to be rationalized in order to be applicable in low-income developing countries where housing scarcity is most acute. One way is to make a synthesis between the industrialized housing construction and indigenous construction technologies. This will hence serve people specifically according to where they live.

Agriculture had remained the main activity in the developing world. However, it is hampered by erratic rainfall which is to a large extent unpredictable and degradation of land through erosion etc. Engineers need to develop means of catching, retaining and storing substantial amounts of rain water when it rains and enable agriculture to be carried out independent of rainfall seasons. Currently, some attempt has been made to store the rain water in containers, but for a substantial amount to be stored, it will be necessary to store the water within the agricultural land itself.

The construction industry has continued to dump tons and tons of debris from demolished structures as wastes from construction sites. The engineers need to come up with schemes which will make use of all the debris in new works. This will entail a holistic approach where designs are made in such as way that in case of demolition the resulting material can easily be incorporated in new works. This may require international cooperation where universal standards will be employed instead of the current practice in which each country has its own standards.

To enable the proposals made above to take place, engineers need to be more involved in both political and financial decision making. Apparently, urban transportation problem, a toxic emissions problem and housing crisis are debated at political meetings. Civil and mechanical engineers need to participate in these debates so that alternative solutions to problems can be evaluated before a decision is made. Unfortunately, most engineers are hired/involved after the decision to undertake a particular project has been made. In an increasingly technologically dependent society, engineers have both valuable contributions to make and a growing responsibility to have their voices heard before the budgets are set and the contracts tendered. Also, engineers need to own and run some of the projects they conceive instead of just designing and constructing/manufacturing for other parties to own. This will give the engineers a better insight of the life-cycle aspects of the projects.

5. CONCLUSIONS

The aim of this paper has been to discuss the areas in which Civil and Mechanical engineering can make contributions in 2000 and beyond. Rather than making mere predictions, the science which is not perfected, the paper reviewed civil and mechanical engineering practice in the pre-industrial era and in the present era with the view of deriving what can be learned from them for incorporation in the practice for future.

The civil and mechanical engineers of the pre-industrial era worked as a team and in most cases individuals worked in both fields. There was no demarcation between civil and mechanical engineering practices. The main driving forces for the practice were; quest for mechanization search of prime-movers to replace human and animal power and search for means of transportation for bulky materials. Engineers of this era explored natural resources such as wind and water to provide solutions. Projects were established on a mini-scale to benefit local communities.

The present era which began during the industrial revolution has ushered in tremendous development in infrastructure and industry, but also brought about a split between civil and mechanical engineering which became organized as separate practices. This era has witnessed several problems including environmental degradation, homelessness and overcrowding in cities and production of large quantities of mass destruction equipment.

The future practice in civil and mechanical engineering has much to learn from past experiences. This includes exploitation of renewable natural resources for prime-movers and construction. Projects to be established on mini and micro-scale to avoid environmental damage, to service the local communities and to be manageable. The world has become a global village and hence barriers have to come down in standardization etc. There will also be movement of people from crowded cities to rural areas in both the developed and underdeveloped countries, if amenities are made available. Due to the exponentially rising world population and shrinking agricultural land, food security is likely to become a defining issue surpassing even military security in the 21st century. Hence agriculture has to be improved through more rigorous research in better management of water and crop land.

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