SESSION 1

Energy and Agriculture

G. PELLIZZI

Well, Ladies and Gentlemen, we can start. The second subject of this meeting is connected with the problem "Energy and Agriculture". Before giving the floor to Dr. D.J. White, for his Chairmanship, I should like to underline that under distribution we have a comprehensive index of non-food utilization of vegetable oils, with approximately 400 references.

Dr. White, I thank you very much for acting as Chairman. You have the floor.

David J. WHITE - Session Chairman

Thank you very much, Prof. Pellizzi. We are running somewhat behind time so I think what we shall have to do is to try to steal some time back from the discussion time, because presumably we should break for coffee at 4 o'clock and we should keep to that. I wonder, should we bring forward the third paper? If yes, we'll see what we can do along those lines. We have three papers in this Session, which is concerned with energy and agriculture, and of course we all know just how important energy is to agriculture. And of course we have a very heavy dependency on limited supplies of fossil fuels. Fossil fuels are needed, not just to drive prime movers but they also appear in other agricultural inputs, such as the manufacture of machinery and of course very much so in the fertilizers and in the pesticides that we use in agriculture. So we are very heavily dependent on limited resources of fossil fuels and this was highlighted by the Yom-kippur War in 1973, when oil prices received a very sharp increase. And of course we have been lulled into a sense of false security since then, because energy prices have actually come back to levels now which are comparable to those which existed in the pre-1973 situation. What has happened is that we have gone on making more and more discoveries of fossil fuel resources, but we all know that there will be a day when fossil fuel supplies really will diminish and then we shall have to start thinking about what we do next.

We have three contributions in this Session and we shall be talking about alternative fuels and also the engines that may burn these fuels. The three papers have been prepared by Prof. Ortiz-Cañavate, Dr. Hermann and Prof. Riva.

So I'd like to introduce the first Speaker, Prof. Ortiz-Cañavate, to talk to us about the characteristics of different types of fuels, namely gaseous, liquid and solid fuels from biomass and the all-important matter of the energy balance that *you* can actually get from these fuels.

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CHARACTERISTICS OF DIFFERENT TYPES OF FUELS (GASEOUS, LIQUID AND SOLID) FROM BIOMASS AND THEIR ENERGY BALANCE

1. Introduction

In many places in the world, and specially in the USA and Europe, it has been frequently proposed that the development of alternative crops and markets for agricultural commodities, like biofuels, might result in more productive uses of the cropland.

In the new Community Agricultural Policy (CAP) from the 128 Mha planted in the EC in 1991, it is intended to take 7 Mha out of food production in 4 years. The reason is the enormous cost of stocking agricultural surplus commodities, that represents a cost to the EC budget of around 140 MECU per week.

Possible solutions for this excess land are:

- to leave this amount of land fallow (set-aside program);

- to change crop orientation toward non-food uses, including the energy crop solution among other alternative industrial uses.

Biofuels, like other renewable energy sources, cannot be considered only as an alternative source of power to fossil fuels when their production is competitive from the economical point of view, but it is also necessary to consider social benefits and environmental protection.

At the current low cost of fossil fuel with a price around 20 US$ per barrel of oil, biofuels cannot be competitive only from the standpoint of the cost of fuel energy. In this respect, it is necessary to consider that in the use of fossil fuels, only the price of extraction and refining are considered, while in the case of biofuels the cost of production must be added. When we consider earmarking a specific amount of land for producing energy for the farm, in fact, the situation is similar to what it was before the mechanization revolution in agriculture, when around 20% of the total surface was devoted to obtaining fodder for draught animals like horses, cows and mules.

The purpose of this paper is to consider the characteristics of different types of fuels obtained from biomass and to compare their energy balance for the gaseous and liquid biofuels that can be applied to conventional engines.

2. Gaseous biofuels: biogas and producer gas

The use of biological products and residues to obtain fuel gases for energy can be made by two ways of conversion:

- dry products can be incompletely burned to obtain producer gas;
- wet or semi-wet materials can be employed in anaerobic fermentation to produce biogas.

The application of these gases as fuel is not new. With the spreading of municipal waste-plants in the most advanced countries, the use of biogas obtained in anaerobic fermenters to run stationary engines to produce electricity represents a substantial saving in plant operation. In Europe during World War II producer gas was used broadly in spark ignition engines in automobiles, trucks and military vehicles.

The use of biogas for energy can be as: warm water (heater), steam (boiler), motive power (engine) and electricity (electric generator). The main problem of this energy is its storage: a small amount of gas can be stored, the heat of hot water or steam is dissipated and electricity cannot be stored. For that reason when there is an excess of gas, in many cases it has to be flared.

Gaseous fuels can be applied very easily in internal combustion engines. One advantage is that they mix more thoroughly with air to burn more completely than liquid fuels. Also they produce a smaller amount of contaminating pollutants, less sludge in the lubricating oil, no wash down of cylinder wall lubrication during engine starting and less valve burning. Another advantage of these gaseous fuels over petrol is their high octane number. Producer gas always surpasses the value of 100 in the octane number (110-115), and methane goes above this value to 125.

This quality permits the use of these gaseous fuels with a high compression ratio (up to 10 and even more in spark ignition engines and higher than 15 in dual-fuel diesel engines), with the result of increasing the performance in the efficiency and power of the engine.

In **Table 1** properties of biogas and producer gas are given in comparison with other gaseous and liquid fuels. The composition of biogas and producer gas is not constant and it depends of the running conditions of the digester gas and of the gasifier.

In biogas the most important component from the energy standpoint is methane, with a heating value of 35.9 MJ/m^3 (10 kWh/ m^3). With a critical temperature for liquefaction of - 82°C, methane cannot easily be liquefied. Some authors [9] have used compressed gas at 200-220 bar in cylinders of 0,05 m^3 capacity and others (Steinmetz et al 1986) have used liquefied biogas applied in both cases to fuel tractors. Other tests conducted in Germany [9] and Switzerland [5] show that this last possibility, although technically feasible, is of no economic interest. All these experiences show that the application of biogas to vehicles is not economic and that its practical utilization is only suitable for stationary motors.

The properties of biogas as an engine fuel can be summarized as follows: low heat content per volume of gas (20 Mj/m^3), high octane number (125) and a low speed of combustion; producer gas has a lower heat value (5.6 MP m), a lower octane number (100-105) and also a low speed of combustion.

2.1 Mass and energy balance for producer gas

Producer gas can be obtained from different sources: wood, straw, nut-shells, maize-cobs, etc. The potential of wood-crops and straw for direct burning or for obtaining producer gas is quite large. As an example [2], let us consider the mass and energy balance for straw from I ha of wheat. The amount of straw produced is 6,400 kg/ha. This straw can be considered as a residue, since the grain is the main objective of the culture; for that reason the only energy considered in the process is the equivalent consumed in collection, transport and pelletizing. The solar energy referred to the straw is a proportional port of the total solar energy used by the crop. **Table 2** provides the values of the mass and energy flow diagram, referred to 1 ha.

When producing fuels by energy cropping, a knowledge of the total energy balance is very important for determining whether we obtain a good result and comparing it to the results obtained with other crops. There are usually two ways to do it:

— calculate the ratio between output and input energies;

— obtain the difference between output and input energies, which is called "net energy production" or "net energy gain".

In this case we obtain a net energy gain of 57.1 -(17.7+1.8+0.6)=37 GJ/ha or an energy output/input ratio of: 57,1/20.1 = 2.84,

2.2 Mass and energy balance for biogas

Most of the biogas produced in agriculture comes from residues of animal production in anaerobic plants. The main goal in this process is the treatment of these residues for environmental protection. But it is possible to consider energy crops like silage grass, miscanthus or sugar-beet leaves for producing biogas.

As an example [11], let us consider the mass and energy balance for I ha of grass for silage. The production of a mid-intensity grass plot is 50 t/ha, which represents 10 t/ha of dry matter or 170 GJ/ha of energy. The energy consumed by 1 ha is:

Tillage, cultivation and harvest	6.I GJ/ha
Transport to the anaerobic fermenter and back	2.7 GJ/ha
Fertilizer	16.5 GJ/ha
Machines and buildings manufacturing	2.1 GJ/ha
Total technical means	27.4 GJ/ha

The energy equivalent for the anaerobic digester is estimated at 2.4 GJ/ha. **Table 3** gives the values of mass and energy balance for 1 ha of silage grass for biogas production.

Considering both energies as useful (heat + fertilizer) we obtain net energy production of (52.9 + 9.4) - (27.4 + 2.4) = 32.7 GJ/ha or an energy output/input ratio of: 62.3/29.8 = 2.1.

3. Liquid biofuels

For engine operation and for most power applications, liquid fuels are currently used rather than the other two states, solid or gaseous.

Liquid biofuels can be in the form of alcohol or oil, and these two types of fuel with their derivatives are applied to Otto-cycle and Diesel-cycle engines, respectively.

Table 4 indicates the energy values of sunflower and rapeseed oils compared to ethanol obtained from sugar beet, maize and wheat.

3.1 Vegetable oils

Vegetable oil can be produced from more than 300 different plants. In most cases, the oil is contained in the seeds or fruits. A distinction between field and tree crops should be made: the highest oil yields can be found in three crops (palm oil, olive oil), however the harvesting operation is much more difficult than with field crops. Climate and soil conditions, yields, oil content and the need to mechanize production will limit the potential use of vegetable oils to a few crops. Oil produced from such agricultural crops as rapeseed and sun-flower can be obtained at different levels:

— on-farm processing: this model seems rather unsuitable because of the high costs of the expeller-press and the need to refine the produced crude oil for fuel use. Other negative factors include the rather low oil yield from small screw presses and the limited usability by the residual oil;

— cooperative processing: by better exploiting the capacity of the expeller-press, the processing yield improves significantly. The same may be assumed for the necessary refining. The higher oil yield of larger presses, and consequently the better feed quality of the meal, are highly important. A processing capacity of a few thousands tons of oilseeds per year would be an appropriate size.

— large scale industrial processing: usually these industrial plants are equipped with an additional extraction stage. Therefore the best results can be achieved in terms of fuel quality, feedstuff quality and oil yield. Normal plant capacity is a few hundred-thousand ton per year.

We consider two types of vegetable oils according to the way they are obtained:

- by compression and extraction;
- by pyrolysis.

A) Plant oils obtained by compression and extraction

When processing oil seeds for fuel purposes the usual procedures for raw oil production can be used. Further processing of the crude oil, however, permits a simplified refining procedure.

Al) Production of raw oil. It can be performed in two completely different procedures. In larger oil processing plants these are usually used in combination. The steps are the following:

-- pre-pressing. The oil seed pressed mechanically; nowadays screw presses (expellers) are used. Depending on the press, the residual oil content in the feedstuff can be reduced to as low as 5%. Pressing without heating allows a very simple oil production from high oil-content oil seeds (e.g. sunflower, rapeseed). However for higher oil yield, preheating of the seed is necessary;

-- extraction. Here nearly 100% of the oil is removed from the seed by the action of a solvent. Extraction is used for oil production only from seeds with low oil-content (e.g. soybean). Extraction is much more energy intensive than pressing, so it is used in combination with pre-pressing to remove only the residual oil from the expeller feedstuff;

-- by products of raw oil production. Expeller and extraction meals are very valuable protein feedstuffs for animal feeding. They help cover the processing costs;

A2) Refining of crude oil. Fuel utilization of vegetable oils requires a refining of the raw oil. The output of some industrial treatments is "semi-refined-oil". Further processing steps common in oil refining, such as deodorisation and bleaching, are not necessary for fuel applications;

A3) Esterification. As early as 1938 a need for chemical modification of vegetable oils was indicated by Walton (1938), who noted that... "to get the utmost value from vegetable oils as fuels it is necessary to split off the glycerides which are likely to cause an excess of carbon in combustion".

During World War II Chinese scientists developed a batch-cracking procedure for refining "veg-gasoline" and "veg-diesel" from plant oil feedstocks, using tung and rapeseed oils in particular (Chang and Wang, 1947). Some military equipment was kept moving this way.

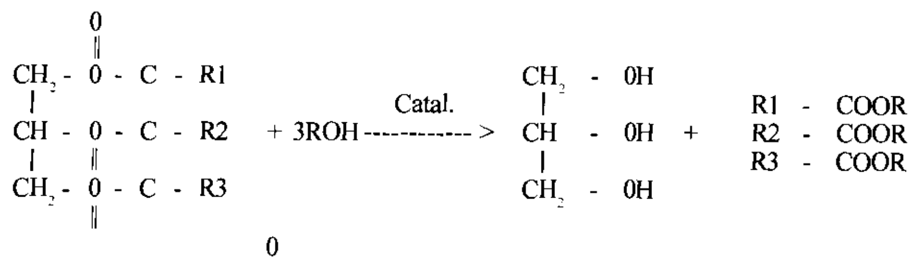
The most widespread idea is that fuel must be adapted to present-day diesel engines and not vice versa. A simple method of adapting plant oils to the requirements of diesel engines is esterification of vegetable oils into vegetable oil esters.

Esterification is a potentially less expensive way of transforming the large, branched molecular structure of the bio-oils into smaller, straight-chain molecules, similar in size to the components of diesel fuel:

The catalyst is aqueous sodium hydroxide or potassium hydroxide. Starting from rape-seed, considering a production of 3,000 kg/ha, the output would be approximately 1,000 kg of RME (bio-diesel), 1,900 kg of feedstuff and 110 kg of glycerine. The exact amounts depend on the production equipment, the process and the type of seed. The economics of the process have to consider the entire picture, i.e. that the end-product is not only oil or RME, but also valuable protein-rich feedstuff for animals and glycerine.

The esterification process was extensively patented in the 40's as widening uses were found for esters. The first report of engine tests on esters is given by Meurier (1952), who conducted exhaustive studies of vegetable-oil esters as fuels. He demonstrated, and others have since verified, the following ad-vantages:

-- vegetable oil-esters have a good potential and are well suited for mixture with or replacement of diesel fuel;
-- methyl- and ethyl- esters are effective in eliminating injector problems in direct-injection diesel engines;
-- viscosities of methyl-, ethyl- and butyl-esters are similar to diesel fuel, significantly lower than the vegetable oils from which they were derived. Methyl-esters are more stable than ethyl-esters and require fewer production steps (Duples-



Triglyceride + Alcohol $\xrightarrow{\text{Catalyst}}$ Glycerol + Esters
(oil)

Example

1000 kg rape oil + 110 kg Methanol $\xrightarrow{\text{Catal.}}$ 110 kg glycerine + 1000 kg RME
(rape oil methylester)

sis and De Villiers, 1983; Quick and Woodmore, 1984).

But unfortunately, there are also problems with the use of esters. Brazilian and German researchers have cautioned about serious lubricating oil deterioration when ester fuels are used, especially methyl esters of soybean oil (Pischinger et al., 1983; Blackburn et al., 1983). The establishment and maintenance of standard ester fuel specifications is a major challenge, and would be essential before a more widespread use would be advisable. Crystal formation in cooler weather was cited as a problem with ester-fuels in USA (Kaufman and Ziejewski, 1983); fuel chemists could likely produce suitable additives to solve this particular problem.

A4) Cracking. It is another procedure to modify the triglyceride molecule of the oil [10]. However, the cracking products are very irregular and more suitable for gasoline substitution, The procedure has to be large-scale, costs are considerable and conversion losses are also sizable; these negative aspects, along with the much lower efficiency of gasoline engines, make the cracking procedure less interesting;

A5) Properties and characteristics of different oil fuels. There are many tables of properties and characteristics of several vegetable oils and their methyl esters compared with those of Diesel fuel. **Table 5** offers a summary of these properties;

A6) Mass and energy balance for vegetable oils. As an example [7], we have considered the mass and energy balance for I ha of rape. Values are indicated in **Table 6.**

When considering rape seed oil (the rape straw is not used normally) - though rape cake is useful as animal feed - we obtain a net energy gain of (42.3 + 24.6) - (20.1 + 3.4) = 43.4 GJ/ha or an energy output/input ratio of: 66.9/23.5 = 2.8.

Considering rape seed oil methylester (RME) and other useful by-products as outputs:

RME + Rape cake + glycerine and

as inputs:

technical media + oil mill + refining + methanol + transesterification

we obtain a net energy production of (40.6 + 2.1+24.6)-(20.1+3.4+ 1.8 + 2.5 + 0.4) = 39.1 GJ/ha or an energy output/input ratio of 67.3/28.2 = 2.4.

B) Plant oils obtained by pyrolysis

The type of oils obtained by pyrolysis of biomass are similar to heavy fuel oils suitable for burning in furnaces, but not to be used as such in internal combustion engines. In this case, these bio-oils have to be upgraded to gasoline and diesel-fuel.

It is not possible to provide any mass or energy balance in this process, because it is now being researched with small facilities in laboratories or at most in pilot plants. A pyrolysis pilot plant in Riano (Italy), running on dry wood (about 500 kg/h), produced 25% wt of char and 20% wt of bio-oil.

In another small laboratory plant at the Federal Research Center for Forestry in Hamburg (Germany), the material balance reveals that 36 parts of net product oil can be obtained from 100 parts of dry wood. With respect to the energy balance, it may be said that 59% of the input energy is stored in the net product oil.

Density of pyrolysis oil is always over 1,000 kg/m'. The water content in the oil is around 10-14%, and for each kg of oil burned 100-140 g water is evaporated. For that reason its heating value is around 25 MJ/kg, much lower than fuel-oil (40 MJ/kg). It is expected that these heavy oils will be utilized more in turbines for producing electricity than in internal combustion engines.

3.2 Bioalcohols

In the near future, the most interesting bioalcohol would be bio-ethanol. It must be emphasised that there is no chemical difference between ethanol derived from biomass and ethanol of fossil origin. The term bio-ethanol merely indicates that the ethanol is derived from biomass.

Bio-ethanol can be obtained from several agricultural products. Currently the most important sources are sugar cane in Brazil and corn in the USA. In Europe cereals (wheat), sugar beet, sweet sorghum and Jerusalem artichoke are used. In Southern countries like Italy, Spain, Portugal and Greece, grape juice is also used, due to the surplus of wine. This last option cannot be competitive. **Table 7** shows the alcohol conversion values for the four main crops indicated. The most traditional crop, and one of the most promising for the production of ethanol in the EC, is the sugar beet. As an example [8], **Table 8** analyzes the mass and energy balance for 1 ha of sugar beet.

Considering as useful outputs ethanol, beet -cuts" as feed for animals and crowns and leaves for organic fertilizer, we obtain a net energy gain of (115 + 40 + 13) - (32.9 + 15.2 - 80.7) = 39.2 GJ or and energy output/input ratio of: 168/128.8 = 1.3.

4. Solid biofuels

The main solid biofuels considered are straw from cereals and chopped wood from ligno-cellulosic crops, like trees (willow, eucalyptus, poplar, etc.) or special grass crops, like miscanthus, which can be transformed into chopped loose material or pellets. Solid biofuels are used for direct combustion in furnaces and may be in the form of:

— loose wood (classified and not classified sizes);
— wood chips;
— briquettes;
— loose chopped material;
— charcoal.

The main applications of solid biofuels are:

— household and industrial heating;
— electric power production.

5. Conclusions

Biofuels may be considered an important source of renewable energy in the future. It is important to establish the energy balance for each energy crop in the different areas of production in order to determine whether it can become a significant energy crop for the future.

The EC and other states, or groups of states, in the world should promote the use of biofuels by means of direct aid or privileged tax treatment for these fuels, which may be considered a source of benefits to society (energy production instead of leaving the land fallow) and to the environment (the CO, cycle is closed and there is no increase of the greenhouse effect) and also a way to diversify energy sources.

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Table 1 - Biogas and producer gas compared to other gasseous and liquid fuels

FUEL TYPE	TYPICAL COMPOSITION	MINIMUM HEAT VALUE		STOICHIOMETRIC AIR/FUEL RATIO	HEAT VALUE MIXTURE	OCTANE NUMBER	CRITICAL VALUES	
		(MJ/m^3)	(MJ/kg)	($m^3 air/m^3 fuel$)	(MJ/m^3)	(N.O)	(°C)	(bar)
Biogas	60% CH_4 40% CO_2	21.6	17.8	5.72	3.21	> 120	-36	76
Producer gas	23% CO 18% H_2 10% CO_2% 49% CH_4	5.57	5.05	1.17	2.57	> 100	-130	51
Methane	CH_4	35.9	50.1	9.53	3.41	115	-82.5	47
LPG	90% C_2H_2 10% C_4H_{10}	93.5	46.3	–	3.68	112	90	44
Diesel fuel	$C_{16}H_{24}$	–	41.8	–	3.97	–	–	–
Gasoline	C_8H_{16}	–	43.1	–	3.77	> 90	296	24.2

Table 2 - Energy and mass balance for 1 ha of wheat straw (Source: [2] modified)

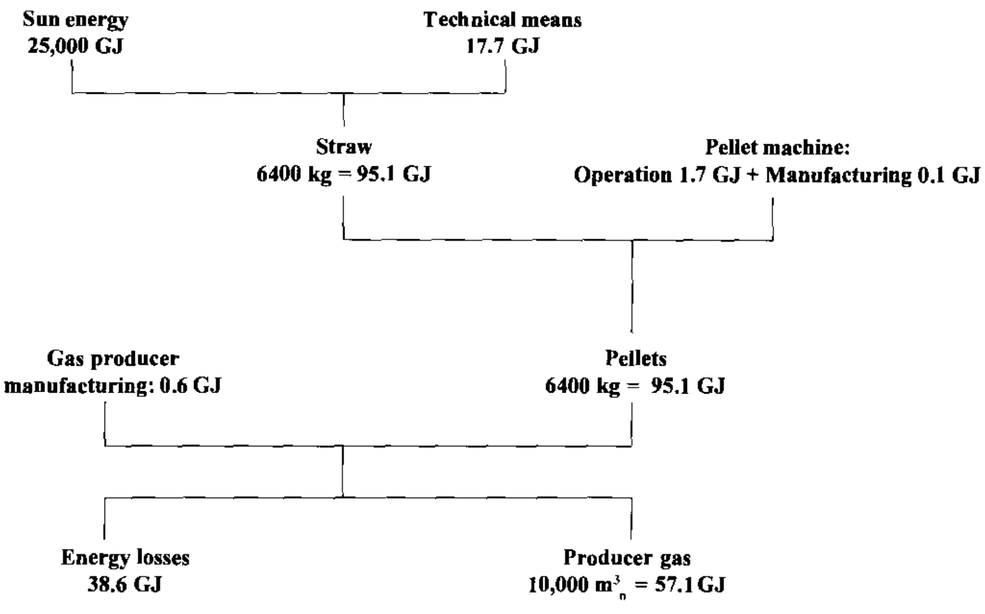


Table 3 - Energy and mass balance for 1 ha of silage grass to produce biogas (Source: [11] modified)

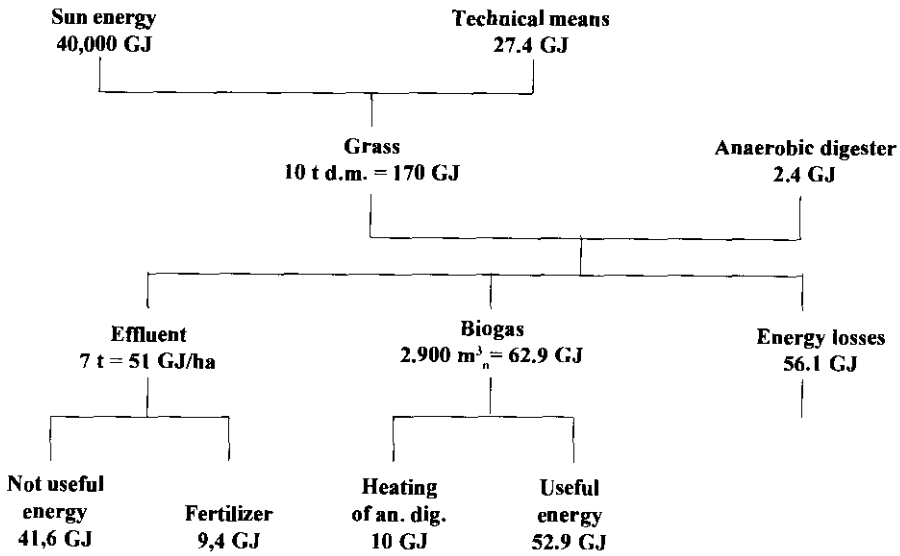


Table 4 - Energy balance for some energy crops (Source: [10], modified)

CROP PRODUCT	YIELD PRIMARY PRODUCT (kg/ha)	ENERGY RATIO OUTPUT/INPUT	NET ENERGY GAIN OUTPUT-INPUT (GJ/ha)
Sunflower oil	2,600	2.8	43.3
Rape-seed oil	2,700	2.8	43.4
Ethanol from:			
Sugar beet	60,000	1.3	39.2
Maize	7,700	1.3	18.4
Wheat	4,400	1.1	5.2

Table 5 - Fuel properties of vegetable oils and their methylesters in comparison with Diesel fuel (Source: Guibet, 1988; Pernkopf, 1988; modified)

FUEL PROPERTY		DIESEL OIL	SUNFLOWER OIL	SUNFLOWER METHYLESTER	RAPE OIL	RAPE OIL METHYLESTER
Specific gravity	(kg/dm³)	0.835	0.924	0.88	0.916	0.88
Viscosity	(cSt)					
at 20 °C		5.1	–	–	77.8	7.5
at 50 °C		2.6	34.9	4.22	25.7	3.8
Heat of Combustion						
Gross	(MJ/l)	38.4	36.5	35.3	–	–
Net	(MJ/l)	35.4	34.1	33.0	34.3	33.1
Cetane Numbert		46	33	45-51	31.4	47.8
Carbon residue	(%)	0.15	0.42	0.05	–	–
Sulphur	(%)	0.29	0.01	0.01	–	0.002

Table 6 - Energy and mass balance for 1 ha of rape (Source: [7] modified).

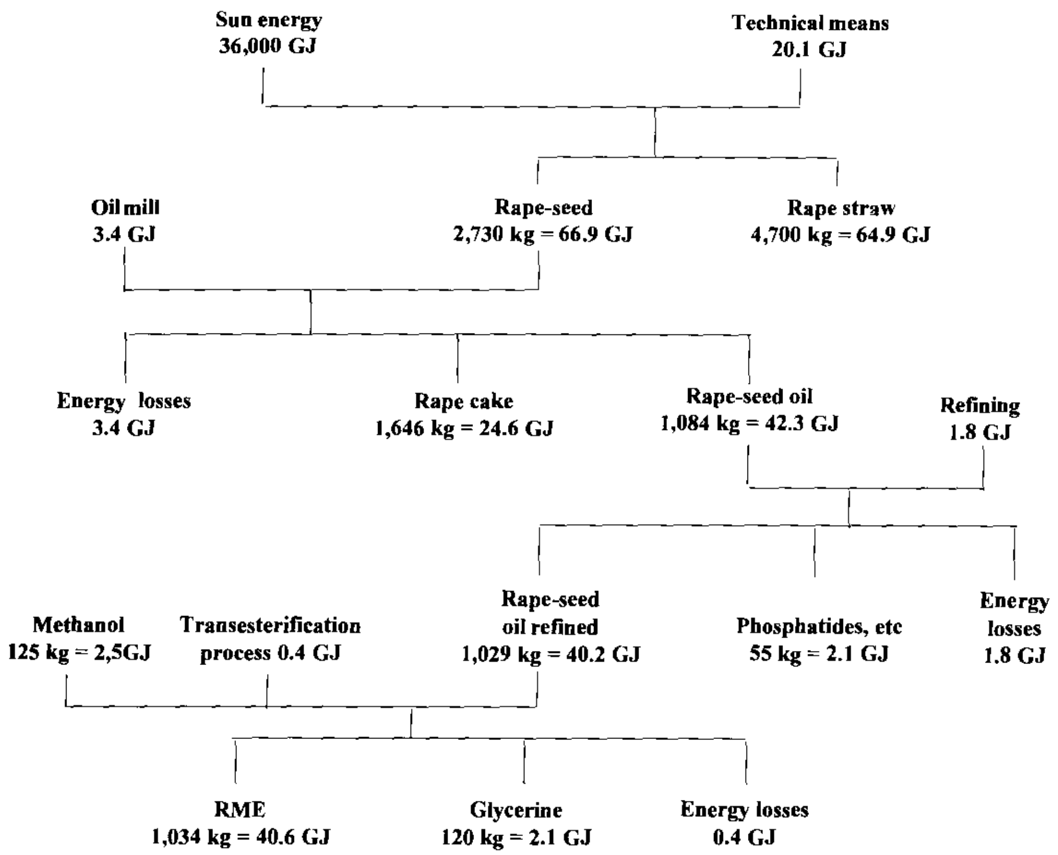
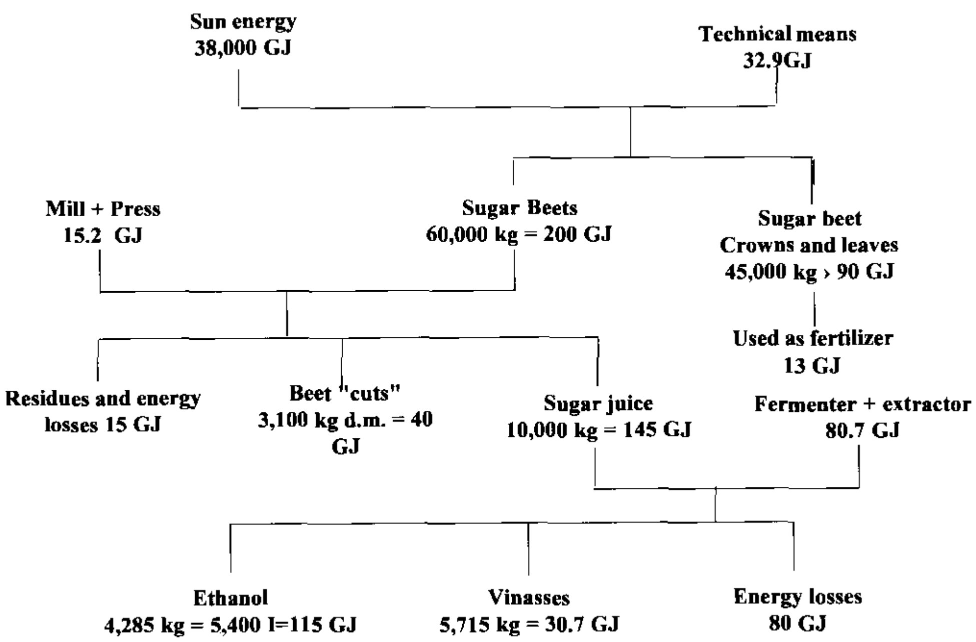


Table 7 - Production of ethanol from different crops

		WHEAT	SUGAR BEET	SWEET SORGHUM	JERUSALEM ARTICHOKE
Yield	(t/ha)	6.7	60	70	70
Conversion factor	(l/kg)	0.37	0.09	0.053	0.08
Ethanol production	(l/ha)	2,480	5,400	3,680	5,600

Table 8 - Energy and mass balance for 1 ha of rape (Source: [8] modified).



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ENERGY AND AGRICULTURE. APPLICATION TO CONVENTIONAL ENGINES

Since the first worldwide oil crisis in 1973, there has been a steadily increasing interest in alternative, renewable, environmentally friendly fuels around the world and especially in a number of Western European countries.

For industry in general, and for the farm machinery industry specifically, there are numerous inducements to work toward respective solutions (**Figures 1, 2 and 3**):

— ecological;

— economical;

— political;

— industrial;

— agricultural.

Taken individually, some of these inducements might seem to lack a real scientific, economic, or ecological foundation. However, they exert enough pressure on politicians and industry to react.

Numerous projects were and are being conducted on various sources of alternative fuels for gasoline and Diesel engines. As farm machinery engines are generally Diesel-cycle, this presentation concentrates on alternatives to Diesel fuel. Various attempts to substitute Diesel fuel have failed due to incompatibility with current engines or because of non-competitive prices.

The first projects having the potential for success were conducted in Europe.

Due to the climatic conditions in the major industrial and agricultural countries of Western Europe, rape-seed became the favourite base material for Diesel fuel substitutes. Thus, it should be allowed and feasible to center the following discussion around rapeseed-oil-based products.

As mentioned earlier, the current research and development work on Diesel substitutes started in 1973 (**Figure 4**).

Retrospectively, the Austrian approach was the most practical, near- and mid-term future oriented one leading to the Austrian 1973 "Bio-Fuel Research Project", which consisted of three major phases (**Figure 5 and 6):**

— vegetable oils in general;

— transesterified vegetable oils;

— rape-seed oil methyl ester (RME).

The reasoning for this project was most of the previously mentioned constrains plus a number of Austrian specifics.

In 1982 already the first successful tests with RME were run in a modem farm tractor with a direct-injection Diesel engine (**Figure 7**).

In 1987 Austria started the actual research project "Bio-Diesel" (RME) **(Figure 8).** This project had a number of extremely important achievements **(Figure 9).**

The success of the Austrian activities had a signal effect for other European countries, and in the years 1990 to 1992 things started to develop more rapidly, aimed at short-term practical solutions (Figure 10).

After the first CEC working group meeting, consensus was reached on the urgency of a Commission proposal for biodiesel specifications for a number of main reasons (**Figure 11**).

Finally in April 1992 the group agreed on a working document with a proposal for biodiesel specifications, which should become the basis for a Commission decision or directive.

In summary, the two most important European approaches on biofuel can be rated as in **Figure 12.**

The success of biofuel is, however, highly dependent on:

— tax treatment;

— political decisions on subsidy programs;

— world market prices of:
diesel fuel
rape-seed
RME by-products (glycerin, rape-seed cake).

Figure 1 - Inducements for activities towards biodegradable, renewable fuels for diesel engines

ECOLOGICAL

- Minimize pollution of:
  - Ambient air (engine exhaust emissions)
  - Atmosphere (ozone layer attacking CO_2)
  - Soil
  - Water
- Avoid monoculture farming
- Reduce fertilizer, herbicide, pesticide use

ECONOMICAL

- Find industrial non-food-type farm products
- Create additional farming income
- Avoid surplus food production/storage or land set-aside programs
- Lower fertilizer, herbicide, pesticide use
- Save limited resources of petroleum and natural gas
- Find renewable energy resources

Figure 2 - Political inducements

POLITICAL

- Concerns about farming income
- Concerns about environmental protection
- Subsidizing programs for:
  farm products, storage, imports, exports, disposal
- Increasing voter support by
  - Swimming on the "green wave"
  - Promising additional farming income

Figure 3 - Industrial and agricultural inducements

INDUSTRIAL

- Producers of bio-fuels
- Inventors of multifuel engines
- Engine tuners modifying engines to accept vegetable oil fuel

FARMING RELATED

- Additional income from industrial-type farm products
- On-the-farm fuel production
- Land set-aside programs not popular
- Dependence on unpopular subsidy programs

Figure 4 - Research and development work on Diesel substitutes

1973 - First world oil crisis gave reason to intensify research activities on alternate fuels. Dependence of farm machinery engines on diesel fuel and crisis providence for agricultural production were major concerns. Vegetable oil based fuels most interesting candidates.
Early research results confirmed that direct injection engines (those most used in farm machinery) were not compatible with pure vegetable oil

TWO DIFFERENT APPROACHES:

- Adapt engines to fuels (mainly Germany)
- Adapt fuels to engines (mainly Austria)

Figure 5 - 1973 Austrian Research Project (phases I, II)

REASONING FOR VEGETABLE OIL AS SUBSTITUTE FOR DIESEL FUEL

- Dependence of farm and forestry machinery on Diesel fuel
- Inner-Austrian solution appears to be feasible
- Production of oil seed crops provides advantages in crop sequence and savings from reduced livestock feed imports

REASONING FOR TRANSESTERIFIED VEGETABLE OIL AS BIOFUEL

- Current direct injection engines are not compatible with pure vegetable oil
- Major engine and tractor producers prefer vegetable oil esters
- Agricultural politics demand a quick solution to the agricultural surplus production problems
- Tractor users - without important risk - can test the new fuel
- All Diesel engine owners are potential customers
- Due to the short project lead time opponents cannot avoid biofuel introduction

Figure 6 - 1973 Austrian Research Project (phases III)

REASONING FOR RAPE SEED OIL AS THE BASIS FOR "BIODIESEL"

- Climatic conditions favour rape-seed
- Favourable energy balance
- Rape seed cake is high protein livestock food
- Fuel properties very close to Diesel fuel.
- High potential for all kinds of mixes and alternating operation with Diesel fuel

Figure 7 - Tests with RME

1982 - First successful test with rape-seed oil methylester (RME) in a modern farm tractor with D. I. Diesel Engine (Wieselburg, Austria)

1987 - Austria starts research project "Bio-Diesel" and finds RME to be the fuel having the potential to directly substitute Diesel fuel in farm (and other) machinery

Figure 8 - 1987 Austrian research project

OBJECTIVES

- Identification of fuel type
- Identification of limitations on fuel applications
- Establishing of (quality) standards for RME
- Release of fuel by engine and vehicle producers
- Clarification of environmentally relevant issues

ACTIVITIES

- Build an RME pilot production facility
- Define RME specifications
- Field fleet test with farm machinery (mainly tractors)
- Engine lab durability test
- Evaluation of exhaust emissions, biodegradability and toxicity
- Extension of field test into non-agricultural applications
- Build of RME plants throughout the country
- Establishing of RME standards

Figure 9 - 1987 Bio-Diesel (RME) project major general achievements

- Fuel specifications and production processes established
- Fuel standard published
- Fully compatible with Diesel fuel - biodegradable - no toxicity
- Tractor fleet test with 36 units from major manufacturers and lab tests completed with satisfactory results
- No adjustments made to engines allowing alternating operation with Diesel fuel
- Release for RME obtained from tractor manufacturers
- Seven RME production plants in or close to operation throughout the country:
  - Annual capacity: 25,000 t
  - Sufficient to run agricultural machinery population on RME
  - Litre price equivalent to Diesel fuel

Figure 10 - European situation

1990 – Austrian standards proposal for RME completed
- German Government-sponsored Porsche project confirms pure rape seed oil not being compatible with D.I. Diesel engines
- EWIV (European Economical Interest Association) was founded and established the "Euro Bio-Diesel" project, in essence concentrating on RME

1991 — Austria publishes RME pre-standards
- The Ministry for Agriculture of Baden-Württemberg (Germany) founds the working group on "Vegetable Oils for use in farm (and other) machinery"
- The German Ministry for Research and Technology forms a task force to define RME standards. This group consists of representatives from Diesel engine manufacturers, RME producers, Technical Inspection Boards, etc.

1992 — Commission of the European Communities (CEC) constituted an informal working group with the task of proposing a specifications standard for Bio-Diesel (vegetable oil methylester) reflecting both current "state of the art" production technologies and a consensus among the producers, the oil companies, and the automobile manufacturers.

Figure 11 - Main reasons for a CEC proposal on bio-Diesel specifications

- The expected growth of Bio-Diesel production in the Community, following the detaxation measures already taken by some Member States, and the directive proposal on bio-fuels detaxation adopted by the Commission (COM (92) 36 final)
- The need for a common agreed standard, which could enable fuel producers, researchers, the auto industry and fuel distributors to pursue their work with the same "product", thus avoiding some discrepancies shown in previous test results
- The necessary compromise, which had to be found between a sufficient degree of fuel quality so that it could be used with the present technology of internal combustion motors, and the fact that production costs should not be unnecessarily high.

Figure 12 - Bio-fuel approaches

RAPE-SEED OIL

- Incompatible with current D.I. Diesel engines
- Limited compatibility with prechamber Diesel engines
- Poor cold temperature behaviour
- Potential for use in special engines and certain precup-engines
- Potential for future engine developments
- Potential for on-farm production

RAPE-SEED OIL METHYLESTER (RME)

- Fully compatible with existing Diesel engines - alternating operation with Diesel fuel possible
- Successful testing and release by engine/tractor manufacturers and research institutes
- Fuel standards being available or developed
- Production processes available and being optimized
- Production plants in operation
- Decentralized production on the farm impossible

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USE OF FUELS FROM BIOMASS IN AGRICULTURE. RECIPROCATING THERMAL ENGINES: AN OVER-VIEW AND POSSIBLE FIELDS OF RESEARCH

1. Introduction

The particular situation that has been created in terms of agricultural mechanisation in the industrialized and developing countries demands new strategies of research.

In fact, the former are characterized by a stagnant market, largely due to a certain degree of demand saturation. In the latter, particularly in the poorer countries, there are evident difficulties in spawning economic activities that would justify investments.

Finding a solution to the problem is certainly no simple task. The situation is also aggravated by the probable lack of a real culture within the field of agricultural engineering that studies these aspects on a global scale and obliges experts to abandon the narrow regionalism that is consuming the best energies in the sector.

In any case, some authors are have suggested that:

- the markets of the industrialized countries could be reactivated through the development of agricultural activities for non-food purposes (e.g. [2]) and the study of machinery that is more comfortable and more environment-friendly;
- a better organization of the rural world in the developing countries requires mechanisation better matched to local agricultural revenues (e.g. [19]) and a rational use of local energy sources (e.g. [11]).

It should also be stressed that the particular aspects that characterize the economic situations in the poor and rich countries, though quite different, must be resolved in a common context. It has become clear, in fact, that the evolution of the former has a profound impact on the interests of the latter: prime examples are the problems of migratory flows and pollution [13].

Thus the awareness that certain difficulties of the industrialized countries can be resolved by strengthening and diversifying agricultural activities worldwide should justify, as an initial hypothesis, at least the formulation of renewed R&D programs.

Within this context, the role of reciprocating thermal engines is of fundamental importance and thus far without practical alternatives.

2. Reciprocating thermal engines

Today the market consists almost exclusively of I.C. engines (in the Otto and Diesel versions), which have been the subject of extraordinary technological progress over the past 50 years. There are now around 600 million engine-driven vehicles on the planet (over 60% of which are concentrated in six countries, which represent little more than 10% of the world population [9]). Adding all the stationary applications and small machines not registered, the total number of functioning engines, never assessed, becomes enormous: al-most surely one unit for each 4-5 human beings. And the potential diffusion trend and current energy absorption are staggering: at least 27-30% of total crude oil production [8].

It is impossible to determine the impact of this consumption on the agricultural community except by broad approximations: according to some studies, about 4% (in absolute terms, [16]). The shares become much larger, of course, if the entire rural sector is considered (10-15% ?). The first question is: what are the relative problems associated with current engine development? In addition to the projected depletion of crude oil reserves (at least those economically extractable, which at current rates of consumption seem sufficient for another 30-40 years), the principal problems are:

— the strict dependence of the "standard" engine (at least as far as the rural sphere is concerned) on fuels with very precise physical characteristics. Generally speaking, the various versions of IC engines currently in use can run on diesel fuel, gasoline, kerosene, natural gas and liquid petroleum gas without difficulties. No more than two of these fuels are compatible with a given engine, however. This creates two sets of difficulties, especially in the developing countries: energy conditioning and economic constraints. Not coincidentally, multi-fuel IC engines were produced in the industrialized countries in 1920-40 for agricultural applications (able to run indifferently on gasoline, kerosene, diesel fuel and, if desired, even gas);

— environmental pollution. The continued use of fossil fuels and the deforestation of the planet are causing an increase in the concentration of greenhouse gases in the atmosphere. Their potential effects, though not yet clearly demonstrated by research in this sector, should be viewed with concern. Among these gases, CO, plays a predominant role (55%) [18]. Its containment would be possible through the utilization of renewable fuels, but they are not generally very compatible with current Otto or Diesel engines un-less they are heavily refined. And then there is the problem of noise emissions, an aspect now being studied in the industrialized countries and apparently not an easy one to solve on I.C. engines without costly soundproofing work of the passive variety;

— integration between industrialized and developing countries. This type of trade policy looks rather unappealing today because of the growing investments required and the tendency of payout times to grow in the planning stage. Nonetheless, it is rational to encourage industrial initiatives in the less advanced countries for the production of mechanical components with a technological content well suited to local conditions. The operational opportunities are extremely vast, as are the limitations, fueled primarily by the infinity of socio-political balances and imbalances.

These considerations of a general nature then elicit a second question: are there alternatives to the current I.C. engines or technological possibilities to make them more compatible with current requirements, especially in the agricultural sphere? Limiting the time horizon to the short-medium term, and bearing in mind that the basic need is to have an operationally flexible technology that can produce mechanical energy in the 0-200 kW range, stationary and mobile, one could conclude that:

- the only renewable energy source accessible in terms of costs and required technological levels is biomass. For example: vegetable oils for use in crude or refined form in Diesel engines; alcohols for use pure or blended with gasolines in Otto engines; oils, alcohols or wood-cellulose residues for use in reciprocating E.C. engines. With the use of biomasses, it would be possible to: close the CO2 cycle, limit the other polluting emissions; provide an outlet for agricultural production in the richer countries; make energy procurement less strategic in the poorer countries, etc.;

- a possible technological integration between the industrialized and developing countries could be based on the development and production of certain engines little used today (such as the Rankine engine).

Within this context, it would be advisable to reconsider the prospects offered by fuels of plant origin and reciprocating E.C. engines.

To better focus on the potential sectors of application and to stimulate reflection, therefore, it seems useful to summarize the historical evolution (including future prospects) of the various types of engines used or usable in the rural context. The analysis prepared should certainly not be considered complete, for two sets of problems: difficulties in obtaining information on the state-of-the-art in certain technologies and the need to squeeze the concepts deemed fundamental into a small space.

3. External Combustion engines

There are basically two feasible cycles: Rankine and Stirling. The related implications are so different that they must be analyzed separately.

3.l Rankine cycle

The first applications in agriculture

From an historical standpoint, the application of the steam engine in agriculture seems to date from 1619. A patent granted by James I makes clear mention of a plow driven by fire engines. A pumping system was surely applied in 1663, built and installed by Marquis (UK). This was followed in 1700 by the well-known industrial applications of Newcomen, Savery and Watt (who was credited for introducing the double-action piston).

After Waterloo, in 1810, a patent by Pratt (UK) makes clear mention of machines for soil cultivation drawn by chains driven by stationary steam engines, and in 1835 the first true demonstrations of funicular plowing were conducted in Lancashire (UK) by Heathcoat and Parkes. They registered a working capacity of 0.22 ha/h (plowing depth 0.23 m) [6].

Interest in this technology thus began to develop. In addition, the invention of the reaper by McCormick in 1831 and the thresher in 1837 by the Pitt brothers (USA) created a real commercial demand of "belt power". Consequently, even before 1850, the steam engine began to be applied on a rather broad scale. The early versions were moved around by animal traction, power varied from 3 to 25 kW, the weight/power ratios were on the order of 600 kg/kW. The fuels used were coal, wood and straw. The application to plowing, in particular, involved two precise technological choices: stationary engines with plows moved by cables and self-powered models for the direct drafting of the plows (forerunners of today's tractors). An analysis of the existing bibliography suggests that the former system was developed primarily in Europe, the latter in the USA.

In 1851 there were 8,000 "portable" steam engines in the UK.

In 1868 in the USA there were models available for the direct traction of plows within a power range of 7 to 50 kW. The advancement speed was 2 to 5 km/h. The work capacity in plowing reached 2 ha/h [22]. Performance was already considered so good (a report by the US Commissioner of Agriculture in 1870 mentioned a machine capable of working with six plowshares) that the designers immediately turned their research efforts toward a replacement to the wheels to improve adherence: this spawned the concept of track drive.

Improvements continued at least until 1920, when the steam engines began to experience competition from the more compact internal-combustion engines (first gasoline, then diesel), which gradually became preferred because of their reduced manpower requirement. This, in fact, was the real reason behind the technological conversion (over a span of 20 years beginning in 1910). A steam thresher required two men, just from the energy stand-point, to care for the engine and three to transport fuel and water. This created obvious organizational problems..

Thus Rankine-cycle engines were the true pioneers of agricultural mechanisation in the industrialized countries. In fact, history seems to suggest that it was precisely the agricultural sector that originally stimulated their development (in 1860, for example, the maintenance of draft animals required at least 25% of farm area).

At their technological maturity (1900-20), the machines could reach a weight of 20 t, power could exceed 100 kW and reach peaks of 200 kW. In the USA, at that time, more than 30 companies were producing 5,000 units/year, some of them equipped with steam lifter. The firm Case produced no less than 36,000 of them during the period 1869-1928 and also dictated their end by taking the honors at the Manitoba Plow Trials (probably the most important farming event in the world then) in 1910 with a steam engine and in 1911 with an internal-combustion engine. The British firm Flowers developed 200 types of plows to satisfy the demand for its machines (about 18,000 units produced) that practically operated all over the world on various soil types.

The work pressure typically ranged from 1.0 to 1.4 MPa and was limited for safety considerations. There were two main versions: with horizontal boiler (the most common) and with vertical boiler. In the simplest horizontal boilers, the combustion gases passed directly from the combustion chamber (positioned at the end of the boiler) to the smokebox (at the opposite end) and then to the flue.

The boiler was frequently used as a basic structural element, to which all the other components (engine included) were attached.

Power was transmitted to the wheels by simply trains of spur gears, usually with an intervening clutch.

Total energy efficiency was around 4-6%.

The application of steam engines lasted longer perhaps in the automotive sector (until the late '30s), where first-rate technological levels were achieved in the USA. The 1922 Stanley 740 (weight 1800 kg), for ex-ample, though costlier than similar Otto-engine vehicles, was endowed with especially simple mechanics, which still give pause for reflection **(Figure 1**). The mileage was on the order of 3.5 km/dm' for water and 6 km/dm^3 for fuel (kerosene). In the '30s, when this solution was being gradually abandoned, the water requirement was five times lower.

The same technical level was never widely introduced in farm machinery. The only exceptions, perhaps, were a prototype tractor by International Harvester in 1923 operating at about 4 MPa with a boiler which ran on liquid fuel (highly compact, limiting the overall weight of the machine to 2,500 kg) and the 15-30 Light Steam-Tractor by the Bryan Harvester Company (USA, 1922).

Recent history

In recent years, applications of the Rankine cycle (except those for turbines for power in excess of 400 kW) should be considered marginal. Furthermore, research work was limited and invested capital minimal, especially in comparison with that made available for other forms of construction (the Stirling cycle, for example).

Around 1960, the technology was revived as part of US R&D programs on engines for low-pollution vehicles. The conclusions stated that such engines were costly, relatively inefficient and that the legislative emission levels could be suitably reached by modifying internal combustion engines.

Subsequently, the energy crisis of the '70s brought renewable energy sources before the public eye, including the use of biomass through steam engines. Some studies established that the technology was well suited to developing countries with available ligneo-cellulose residuals and/or products. The reasons are intuitive: the possibility of escaping fuel quality constraints, ease of maintenance, long machine life. The proposals advanced internationally, however, largely remained on paper.

Today is it not easy to find machines suitable for agriculture. The best-known producers are Skinner in the USA, Mernak and Fezer in Brazil, Spilling in Germany and others in Thailand, India and China, of whom little or nothing is known **(Table 1**). These systems are suitable for fixed point operation for the production of electric power, in many cases identical to engine developed in the early 1900's and with power ranging from 5 to 500 kW. They are attributed with the usual defects: high weight/power ratios, limited efficiency (unless cogeneration is used) and high investments. This last aspect seems the most serious: in 1987 the costs of a steam unit in the 10-100 kW range were around three times greater than those for similar Diesel generator groups. In specific terms: 800-1,000 US$/ kW of electrical power [12].

In research terms, the technology is currently being considered by few firms and/or organizations, and the results are difficult to interpret, since it is not easy to procure complete information and compare data from a limited number of sources (**Table 2**).

Bearing in mind the needs of the agricultural sector, the possible paths to follows would seem to be two: the construction of traditional plant schemes in a modern key or the development of innovative engines, obtained by utilizing components found in the market.

Examples of the first type are described by Hislop (Energy for Sustainable Development Ltd, UK). They are 10-50 kW double-acting single-cylinder engines, operating at 0.8-1.0 MPa and 600 rpm. Typical efficiencies are around 6-12%, depending on whether a condenser is used. The boilers are almost always of the water-tube type, known to be less dangerous than the fire-tube variety.

Examples of the second type are furnished by the experimental activity of Australian National University. They are multi-cylinder Diesel engines (Lister) transformed into 60-200 kW single-acting steam engines with condensers, operating with steam at around 7 MPa. The boilers are single-tube, and practical efficiency reaches 15% (ideally 18%). A similar path has been followed by Skinner, who utilizes Diesel blocks from the firm Detroit (6-500 kW), though favoring low pressures, reaching efficiency levels of 8%.

Some reflections

The real advantages offered by Rankine-cycle engines are multi-fueling, excellent torque and the use of a particularly economical, well-known working medium: water. In addition, among the various alternative engines, it is perhaps the most bio-compatible and the most suitable for rural applications, especially in the emerging countries.

Intuitively, therefore, it may have a potential validity in a broad spectrum of operational situations.

In effect, the technology is still being applied. In Thailand, for example, the use of rice husks and sugar cane residues for energy production increased by 500% from 1979 to 1984, thanks to the availability of Rankine technologies. In terms of crude oil, the contribution of these products to national consumption has been valued at 7% in 1970 and 18% in 1984 [19]. Pity no more is known about it.

The principal disadvantages, as we have seen, are limited efficiencies and large dimensions, investments and manpower requirements. From this standpoint, therefore, little has changed since J.I. Case decided, around 1910, to replace its steam-engine threshing machines with I.C. engine types.

One wonders, therefore, what could be done today with an adequate research effort

The efficiency problem can be partially overcome by increasing working pressures (and thus temperatures) and seeking good expansion efficiency. The 5 kg of steam per kWh already reached (around 20% of total efficiency, boiler included) is a more than acceptable result. In many cases, however, the usual efficiency of 5-6% may suffice. It should be pointed out, in this regard, that the Rankine-cycle engine, in addition to being multi-fuel, performs better under partial loads than I.C. engines. Under some operating conditions, current Diesels do not offer extraordinarily higher efficiencies **(Table 3).**

The investment aspect is linked primarily to a market deemed totally marginal, and its greatest limitation, along with the manpower requirement (serious problems in some social conditions) in the boiler construction.

Consequently, the hypothetical elimination of the boiler would permit steam machinery to compete on equal terms with Otto and Diesel types and therefore offer significant practical advantages.

This is obviously not possible in absolute terms, but an example of what action could be taken in this direction was suggested recently by Bialostocki: injection of water into a heated cylinder from the outside **(Figure 2**).

The system, philosophically more congenial to the modern engine culture, would offer the highly interesting advantage, in fact, of eliminating the pressurized water tubes in the boiler and thus open the way to acceptable efficiencies, product simple machines with a high degree of safety and favor mobile-point applications.

One variant, less risky from the engineering standpoint but less promising in terms of innovation, is the injection of water under hypercritical conditions (in this case, the injected water vaporizes instantly).

3.2 Stirling cycle

The early applications

The Stirling cycle, or more exactly all cycles that are identified by this name (with air or hot gas, closed or open, regenerative or not), generating a lot of confusion, have never been extensively applied in agriculture. To describe its development, we must therefore refer to other sectors.

The first known functioning hot-air open-cycle engine was at Cayley (UK) in 1807. The Stirling patent (closed regenerative cycle) was filed in 1816, and one variant (open regenerative cycle developed by Ericsson of Sweden) met with a certain success. According to the contemporary bibliography, a few thousand were apparently installed in Europe and the USA during the 19th century, mostly low-power (0.2-4 kW). They were used on farms to pump water. A few authors indicate a 220 kW engine for ships, built by Ericsson in 1853, as the largest ever built (four cylinders with bore and stroke dimensions of 4 and 1.5 m; 9 rpm).

Thus the hot-gas cycle, despite its intrinsic advantages discussed later, was never able to overcome the Rankine cycle. Stirling himself indicated the reasons why just before his death in 1876: lack of materials suitable for high temperatures; in his opinion, the air engine would have been successful if Bessemer steel had been available before 1840 [23]. In fact, in the late 1800s the performance was interesting: overall efficiencies on the order of 7% (but below 2% in many applications) and great safety of operation (they avoided the risk of boilers under pressure).

Following the diffusion of internal combustion engines and the invention of the electric motor, commercial interest in the Stirling solution was already considered practically null in 1914: no less than 15 years before the steam engine vanished from agriculture.

The second generation of engines

About 1938 Philips began in-depth research in its Dutch laboratories. The initial objective was to develop a small 0.2 kW generator group for radio sets. The first pre-series of 400 units was made available before 1950, but parallel progress in the electrical and electronic fields never triggered a real commercial interest in such generators. Philips there-fore addressed its research in two directions: development of cryogenic machines for super-low temperatures (the Stirling cycle is reversible, in fact), a field that produced some results, and the study of medium-power engines for automotives.

The effort was substantial, and the technological know-how accumulated by the company up to 1980 made it the absolute leader in the sector. The most productive period was surely the '70s, when the automotive industry (particularly Ford and General Motors) became truly interested in the subject. One of the most advanced and best tested products was the famed Ford-Philips 4-215 engine: four cylinders, around 2.5 dm^3 of displacement, hydrogen as a working fluid, average maximum pressure 20 MPa, 4,500 rpm, 200 kW. At reduced power, the efficiency could exceed 30%. The engine thus stood as a direct competitor of the Diesel. Nonetheless, in 1979 Ford decided to abandon the project. They therefore decided to concentrate on I.C., despite the evident success achieved.

As a result, there was a reverse trend in industrial interest and research efforts.

Other single- and multi-cylinder models were developed, for military applications or due to sizable public funding, by Philips licensees (e.g. United Stirling of Sweden) and research institutes (e.g. MIT). The principal objectives were generator groups and heat pumps.

The enormous scientific output of that period is impressive. It led, primarily at the academic level, to the consolidation of a culture around the Stirling cycle, still present and elitist from a certain viewpoint. This interest certainly produced no equivalent practical effect.

This could be explained by two observations: the cycle lends itself to a large variety of engine configurations which probably "dispersed" the efforts of the various researchers (there are so many proposals in the literature that anyone approaching the topic for the first time is confused); the attempt to offer an alternative to internal combustion engines (high specific power and efficiency) led to the study of machines that utilized high-pressure helium or hydrogen, with conceptually simple operation. The practical handling of these gases has always posed significant construction problems, which had a negative impact on the economic aspect and ultimately on application.

As a direct consequence, this particular course of events kept the Stirling engine away from agriculture, even up to recent times.

We must await the '80s, in fact, to hear talk of rural environments. In those years Sunpower Inc. (USA) was presenting a 4 kW single-cylinder air prototype for fixed-point applications fuelable with rice husks. Since then, biomass has been rediscovered as a fuel, spawning a considerable scientific output on the subject, encouraged, perhaps, by the availability of funds for international cooperation.

Again in this case, however, the practical applications were strictly marginal.

Some reflections and current status

Viewed from outside, the evolution of the Stirling engine presents some fascinating aspects from an engineering standpoint but also leaves some perplexities because of its lack of commercial results (except for some highly particular applications).

What drove such a multitude of scientists and engineers to concern themselves with the subject?

In effect, the favorable characteristics, at least theoretically, are attractive:

- all the advantage of an external combustion engine (emission control, possibility to use various energy sources, including solar and nuclear, etc.);
- noise and vibration levels reducible to minimal values;
- closed cycle: it is therefore possible to create "hermetic" engines, not subject to contamination and long-lasting; reversibility of the cycle (it is conceptually possible to accumulate heat when braking);
- good specific power and torque;
- high thermodynamic efficiency;
- simplicity of operation.

The last two advantages)are most probably sufficient in themselves to justify the attention of researchers and to make the Stirling cycle more "noble" in the eyes of many than the other cycles (particularly the Rankine).

The theoretical efficiency, in the current state of technology (temperature of the heat source around 800°C and average working pressures below 20 MPa), reaches 67% (40% has been achieved in practice) versus 60 and 63% for the Otto and Diesel cycles, respectively. If it were technically possible to raise the heat source temperature to around 1,300°C, it could reach 80%.

The Stirling engine has thus found is greatest limitation in materials (which, unlike internal-combustion engines, must actually sustain the heat source temperature). Its mechanical simplicity derives primarily from the use of valveless engine schemes. The need to regulate the power, however, creates other structural complications.

Today engine development is essentially frozen at the '80s. Considering the power levels interesting for farm applications, the organization currently working on the subject are **(Table 4):**

— General Stirling Corporation (Netherlands). This firm comprises all the technological know-how of Philips and its licensees (particularly Stirling Power Systems and Stirling Thermal Motors). Efforts are currently directed at the development of a helium engine that reflects the scheme of the Ford-Philips engine described above. It is a four-cylinder of 25 kW (increasable to 50) conceived primarily for use as a generator group. The power is regulated by varying the thermal horsepower of the burner and the piston stroke by means of a swash-plate mechanism (whose angulation can be varied by means of a hydraulic cylinder). It is silent-running (76 dBA) and vibration-free. This author had the opportunity to stand a coin on its edge on the engine casing of a prototype producing 10 kW on a test stand. Running on natural gas, efficiency can exceed 35%. Demonstrations and applications to a hybrid vehicle are planned for 1993;

- Schlaich & Bergermann and Patner (Germany). This engineering firm, specialized in structures, recently developed an interesting solar dish concentrator.
  Some prototypes have been coupled with V-160 engines of Stirling Power System USA (firm absorbed by the aforesaid GSC) to study a solar power generator with around 5 kW of power, more efficient and economical than the current photovoltaic solutions. The V-160 is an interesting engine with 0.6 dm' of displacement conceived for coupling to refrigerator compressors and electric generators. The power (using helium) can exceed 6 kW at 1,500 rpm, and power is regulated by varying the quantity of working gas (through a pressurized bottle and a small compressor) and the power of the thermal energy generator. Some models are said to have exceeded 40,000 hours of operation. Three of these engines, in different versions, were also tested by the Institute of Agricultural Engineering in Milan [20]. The difficult of procuring the components and sufficient technical assistance induced Schlaich & Bergermann to develop, in conjunction with Solo of Germany, an engine an almost identical engine and it is still able to furnish one to those who request it;
- Aisin Seiki Co. Ltd. (Japan). It is a R&D organization linked to the automotive sector, present throughout the world.
  Its laboratories have developed four engines: the I-SAS200 200 W free-piston type for household and space applications; the SS90, 6 kW single-cylinder for coupling with compressors; the AE89 25 kW two-cylinder for vehicles; and the NS30A 30 kW four-cylinder swash-plate type for general use. This last model seems the most advanced (it has reached 38% efficiency, **Figures 3 and 4**);

- Sunpower Inc. (USA). This firm produces small engine with no rigid connection between piston and engine block (called piston-free technology), the ST-5 4 kW air type mentioned earlier, the only engine designed for farm use and running on solid fuels. It price in 1987 was set a US$ 3,000, while its manufacturing cost was estimated at US$ 750 (190 U$/kW) Ill]. According to various authors, its overall efficiency is between 6 and 10%.

In additional to these organizations, numerous prototypes of small-power (< 1 kW) air-type engines are available at university and/ or engineering company laboratories, but little or nothing is know about their useful life span.

In summary, it is rather evident from this picture that current research on Stirling engines (at least the more operational variety) still favors high-technology solutions and disregards the simpler solutions that could find immediate application.

4. Internal Combustion engines

The Otto cycle engine reached a reasonable level of development in 1876, and the Diesel engine was patented in 1892. Not until the 1909-12 period, however, were they practically introduced in agriculture. Since then, the I.C. engine underwent massive diffusion, reaching its historical peak in the post-W.W.II era and contributing significantly to the creation of the modern rural system.

To review their current status, the topic will be examined here (briefly, as the it is more familiar than the preceding subject) separating the small engines (up to 10 kW) from the medium and high power types (from 15-20 to over 200 kW).

Small-power engines

These appeared in agriculture around the '20s. Initially, the most common applications were of the stationary type: irrigation pumps, threshing machines, corn shellers, etc.; the early structural solutions were based on the Otto cycle (in single- and twin-cylinder versions), generally four-cycle, with lateral valves and air or water cooling. Until the '40s performance increased rather sharply: rotation speed rose from 1,000-1,500 rpm to 2,400-2,800 rpm, specific power from 5-6 to 11-12 kW/dm'. Thanks to the gradual re-placement of cast-iron with aluminum, weight declined from 40-48 to 20-27 kg/kW.

In the late '30s, the first single-piston Diesels with indirect injection and water cooling made their appearance. Their performance was interesting: 6-6.5 kW/dm' at 1,500-1,600 rpm.

The real diffusion of small engine began, however, after the Second World War, with the creation of small self-propelled machinery: since then technological progress has proceeded in parallel with that of farm machinery. The phenomenon became particularly significant starting in the '60s, with the development of the mower (key machine in the development of certain European farm systems such as Italy's) and then the walking tractor and power tiller.

As a result of these developments, the two-cycle Otto engine was relegated to marginal uses. The pre-chamber Diesel and water-cooled Otto, for reasons of size and weight, gave way to the direct-injection Diesel and the four-cycle air-cooled Otto (with lateral or overhead valves).

In the past 25-30 years, essentially, the design philosophy has remained basically the same. Of course, materials, manufacturing technologies and performance have improved: at speeds of 3,000-3,600 rpm, 17-18 kW/dm^3 can be obtained today with Diesels (corresponding to 6-10 kg/kW) and 22 kW/ dm^3 with overhead-valve Ottos. Specific consumption stands at around 240-260 g/kWh for Diesels and 340-360 g/kWh for Ottos.

A significant drive to innovation is provided today by the need to limit acoustical emissions and reduce the danger of gaseous emissions. The former are forcing manufacturers to reduce vibrations and pressure peaks, the former to control thermal conversion better. This will necessarily imply a future increase in costs.

Medium and high power engines

While small engines developed in lock-step with light farm machinery, midsize and large engines followed the development of the tractor, a term coined in 1906 by the firm Hart-Parr (USA) as an abbreviation of the expression "gasoline traction engine".

In the beginning was the Otto engine. The first success was probably obtained by Froelich (forerunner of John Deere) in 1892, followed by many other pioneers (many of whom generated the current manufacturers of tractors and combines) through the years of competition with steam (1910-20). In 1917 the Ford Motor Co. began production in the USA of the famed Fordson model, reporting production of 36,000 in 1918 and 100,000 in 1925 (75% of all the tractors manufactured in the USA that year). And at that point the Rankine cycle (abandoned, perhaps, by the more creative minds) vanished definitively from the agricultural sector.

In 1910 a typical 35 kW Otto engine had 8 dm^3 of displacement (around 4.5 kW/dm') and weighed 400 kg (Il kg/kW).

In 1926 Cassani (Italy) distributed the first tractors with Diesel engines (1 cylinder, 26 kW, 12.7 dm^3, 550 rpm), and in 1931 the Caterpillar Diesel 65 was launched on the US market.

The rapid technological development came after the war, as with small engines, with the massive, practically unchallenged application of direct-injection Diesel engines. The intermediate power segments (40-150 kW) were those that benefited from the greatest improvements: in the '70s, for example, specific power was around 13 kW/dm', reaching 15-16 kW/ dm^3 in the '80s and, thanks to supercharging, to the 22 kW/dm' of today. The trend is to reach 25-26 kW/dm' (3-4 kW/kg) in the short term.

At the same time, specific consumption has gone from the 250 g/kWh typical of the '70s to the current 210-220 g/kWh. For the more powerful engines, the improvements in performance have been less significant, as they were already generally good in the post-war era.

In recent years, the greatest efforts have been directed toward "harmonizing" the wear of the various elements, so as to increase reliability and decrease operating costs.

Medium-term development is linked, even more clearly than with the small engines, to the control of emissions and high-pressure injection. These are the fronts where it is possible to measure the technological level of the various manufacturers today.

Some reflections

An analysis of the evolution of I.C. engines indicates that **(Table 5):**

-- specific power is continually increasing. The objective, in fact, is to reduce the weight/power ratio and, as a result, dimensions and production costs. Since the early Diesels (30-40 kg/kW) weights have been reduced to about 1/4 (6-10 kg/kW). This has contributed greatly to price containment. Not coincidentally, the automotive sector is now considering the use of the more advanced two-cycle Otto engines, which seem to have no rivals from this standpoint (1 kg/ kW). With the application of injection and special valves, in fact, their past defects can be limited: gas emissions and high specific consumption. There is thus no reason why they could not be introduced to agriculture, in the medium-power segment. By way of comparison, the swash-plate Stirling engines now stand at around 8 kg/kW (in line with today's non-supercharged Diesels), while it is not possible to provide plausible data for modern-day Rankine engines;

-- specific consumption (a parameter directly linked to thermodynamic efficiency) has been constantly declining, while for the medium and long term, due to the need to reduce emission, it is expected to remain stable or even reverse the trend (there could even be a return to the pre-chamber Diesel). Fuel quality considerations aside, therefore, only the most advanced Stirling engines can compete today with I.C. engines in consumption terms;

– useful life is decreasing. To avoid confusion in this regard, one aspect must be clarified: in the past, I.C. engines were designed to satisfy the greatest possible number of applications (with few or no modifications). This was permitted and/ or required by a fast-growing market. Today, with demand declining, engines are becoming increasingly specialized for specific uses. The average operating conditions can thus be projected and the design better targeted. At the same time, it should be noted that today's users accept shorter useful lives (closer to actual needs) against a reduction in investment. In this way, to cite an example, the classic useful life of 8-10,000 hours for tractor engines in the '70s has already been scaled down to 5,000 hours. For E.C. engines, on the other hand, the tendency is to design long-lasting engines for heavy-duty applications. This aspect should be clarified in technological terms, since engine of similar lifespan should be considered to have a proper comparison with I.C.;
– reliability is increasing within the framework of reduced useful life. This means that during the course of its "contractual" life, a modern LC. engine requires less ordinary and extraordinary maintenance than one of older design, which may have had two or three times the useful life (with the consequent increase in dimensions, weights and costs). This is a direct consequence of the greater specialization of applications discussed above, the better basic materials and production standards and the increased ability to understand mechanical and thermal stress, due to the enormous research activity conducted on these engines;
– maintenance requirements are decreasing. Taking the '70s as a reference, the intervals of ordinary maintenance have increased by at least 100%. In terms of future trend, the concept of extraordinary maintenance is even disappearing, thanks to the increasingly balanced index of wear on the individual elements. From this standpoint, E.C. engines offer excellent credentials (field-tested only on the Rankine cycle) but would require a more precise picture than currently available.

Concerning the use of renewable fuels, I.C. engines offer the possibility of using: gas produced by the gasification of biomass and the anaerobic fermentation of animal wastes; alcohols; and vegetable oils. The last two are of particular interest, as they replace traditional fuels without upsetting the original operating flexibility of the engine and their manufacturing costs (**Table 6).** Gaseous fuels, in fact, could be considered only for stationary uses.

The Brazilian and US experience, in particular, has clarified the problems linked with the use of alcohols in Otto engines and, economic consideration aside, the technical results obtained in terms of engine production and conversion (those intended to run on pure alcohol have around 300 "specialized" parts different from similar gasoline models) should be better diffused.

In the agricultural world (considered world-wide), however, vegetable oils frequently appear more attractive, for two basic reasons: compatibility with Diesel engines and ease of production.

There is considerable scientific work on the subject, but it proves insufficient to analyze the problem as a whole. In most cases, in fact, it consists of studies on the characteristics of individual oils and short-term tests conducted on the test stand to measure engine performance.

There are currently two basic orientations: the use of esterified oils, pure or blended with Diesel fuel, in normal Diesel engines or the use of crude oils, obtained by simple mechanical extraction, in special motors.

The former possibility is currently being considered in at least three European countries: Austria, France and Italy. In Austria batchtype plants are in operation to produce around 25,000 t/year of methyl esters of rapeseed and sunflower oils. The initiative is being encouraged by the local government and is aimed at the reduction of oil-seed exports. The subsidy level is around 0.9 US$/dm^3 (sum equivalent to the difference between the national and international prices of 3 kg of seed) and no taxes are applied to the product. In technical terms, in-depth research has been conducted [15]. In France, a similar initiative is being organized, while in Italy a private installation of 60,000 t/year of esters is scheduled to open in 1993. The objective is to utilize seeds and/ or oil procured on the international market (where the price of unrefined oil is 0.45-0.5 US$/kg) and making a suitable product available for use in the cities to reduce gaseous emissions. The commercial aspect is valid if the plant fuel is placed in competition with taxed Diesel fuel (which costs from 0.6 to 0.9 US$/dm^3 in the EC).

The use of esters poses very limited engine-design problems, linked in most cases to low-temperature operation and the compatibility of these products with certain components.

The use of crude oils, on the other hand, has been totally ignored, despite the potential interest it could arouse in emerging countries (where spontaneous oilseeds are even avail-able that could not be easily utilized in the food sector) and also in the agriculture of the industrialized countries, despite the extreme ease of production. In effect, it is the only renewable fuel that could really be produced in a decentralized manner with limited plant investments.

This lack of interest can probably be explained by the impossibility of utilizing crude oil in normal Diesel direct-injection engines (in the most interesting power segment) because of its incompatibility with current injection systems. The typical viscosity of 80 cSt at 20°C (versus the 5-7 cSt of standard Diesel fuel), in fact, require a sharp reduction of the injection cone, with a consequent drop in combustion quality and the formation of significant carbon deposits. In general, engines stop running after 150-200 hours. The problems are greatly reduced, and in some cases almost resolved, with the use of indirect injection.

The problems could be completely eliminated with proper design (i.e. single-hole, self-cleaning injectors, turbulence chamber cut into the piston crown, etc.), as demonstrated by the extensive experiments of the Elsbett brothers (Germany). After all, there are Diesel engines available, at the current level of technology, that can utilize fuels of 700 cSt at 50°C.

The possible applications are therefore concrete and should be evaluated within a broad context. A recent analysis conducted by the Institute of Agricultural Engineering in Milan, in fact, revealed the following activities as promising: determination of the regions where the use of crude vegetable oils as fuel is possible, especially if they are produced from indigenous oilseeds of little industrial value; marketing of Diesel engines in the 5-50 kW segment suitable for the use of these oils; experimentation on continuous partial esterification processes (which would produce viscosities suited to current injection systems).

A further point (more interesting for the industrialized countries) that characterizes the use of alcohols and oils is the beneficial effect these products have on emissions (**Tables 7 and 8).** Their oxygen content, in fact, facilitates combustion, even if they are blended with fossil fuels (it has been noted that the effects are evident even at small percentages [14, 17]). This is another point on which many aspect should be clarified.

5. Conclusions

The foregoing considerations seem to suggest that:

- the particular historical evolution of thermal engines has certainly not permitted a harmonious development of the various types, so it is not possible to compare the various structural solutions today because of their different techno logical levels. Legal restrictions must have played a significant role in the creation of this state of affairs. Otto, for example, presented his engine in 1876 but was unable to maintain patent protection for it beyond 1890. This gave a free hand to industrial initiative, and in fact there were already 100 manufacturers of gasoline engines in the USA by 1899. At that time, this freedom surely favored the diffusion of a technical culture on this extensive and operational topic, of which Diesel himself must have benefited. On the other hand, against the marginal applications of the modern Stirling engine there is the considerable protective shield of Philips, which in all probability has induced a less pioneering culture. The stage of development at which the Rankine engine was left (the overwhelming diffusion of the Otto engine certainly left it neither the time or the capital to adjust), does not seem totally convincing, from a farming standpoint. We stress all this to support the hypothesis of an understatement of E.C. engines and the need for greater clarity on their true application potential;

- the need, evidenced in the opening, to utilize fuels other than the traditional varieties favors E.C. engines (e.g. high-technology Stirlings for industrialized countries and Rankine engines for the emerging countries) and some versions of I.C. (e.g. Diesels suited to run on crude vegetable oils). Considering the current state of the art, however, the various engines are not reciprocally competitive but rather candidates for different applications. With this in mind, it would seem of primary importance to evaluate the market potential, in order to encourage and orient industrial initiative, is the results are interesting.

In summary, the engine universe should be reanalyzed at the global level (**Table 9**). Considering that the agricultural sector still plays a decisive role precisely in those regions where the greatest market growth is expected, agricultural engineering would be in a privileged position to conduct this type of operation.

From this viewpoint, therefore, the following analyses could be undertaken:

— potential of E.C. engines in the emerging countries for stationary applications;
— feasibility of the use of crude vegetable oils (obtained from indigenous oilseeds) with special Diesel engines in the emerging countries and vegetable oils at various levels of refining in the industrialized countries;
— the environment and social effects of utilizing renewable fuels;
— identification of I.C. engine solutions that would permit reductions in weight per unit of power.

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Fgure 1-Layout of essential parts of the Stanley 740 (steam-powered car). 1: condenser; 2: boiler; 3: burner; 4: fuel control system; 5: water tank; 6: water pumps; 7: fuel tank (kerosene); 8: steam engine (Source: Stanley Motor Carriage Company; modified)

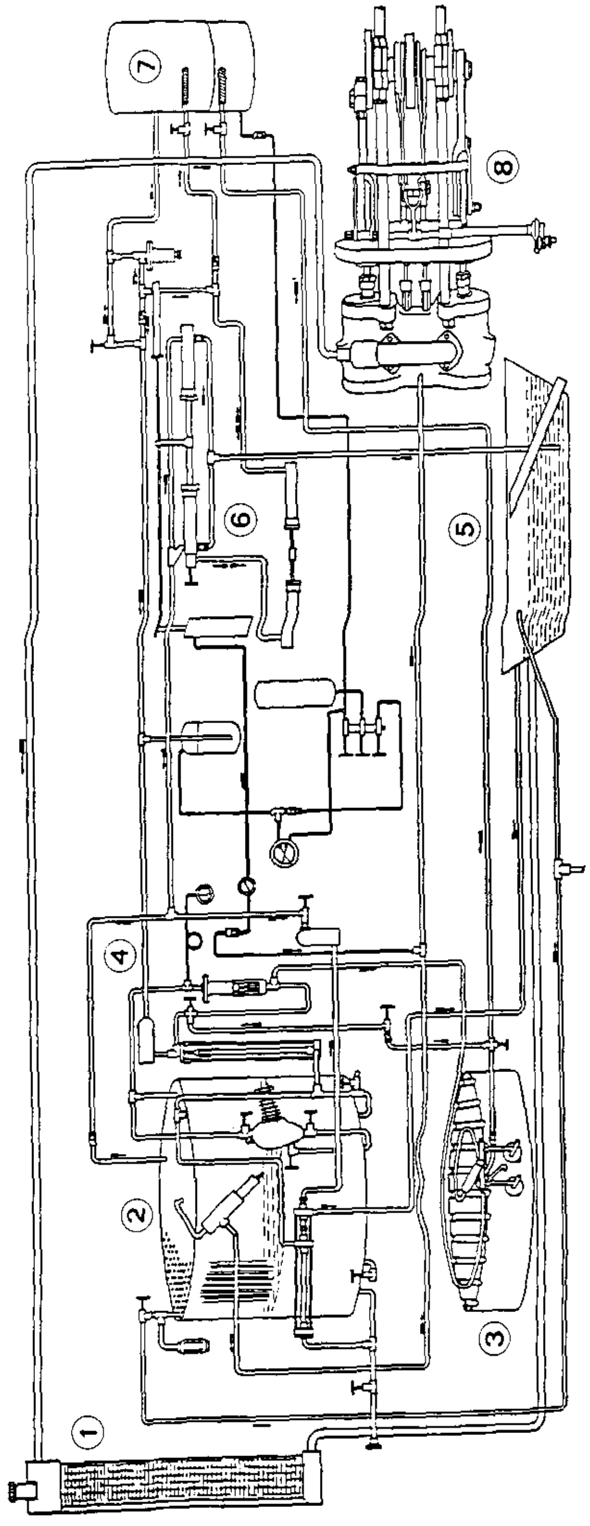


Figure 2 - Conceptual layout of a water injection steam engine. I: furnace space; 2: water injector; 3: no-lubrication power piston incorporating exhaust valve; 4: condenser; 5: high pressure water pump (Source: [4[, modified).

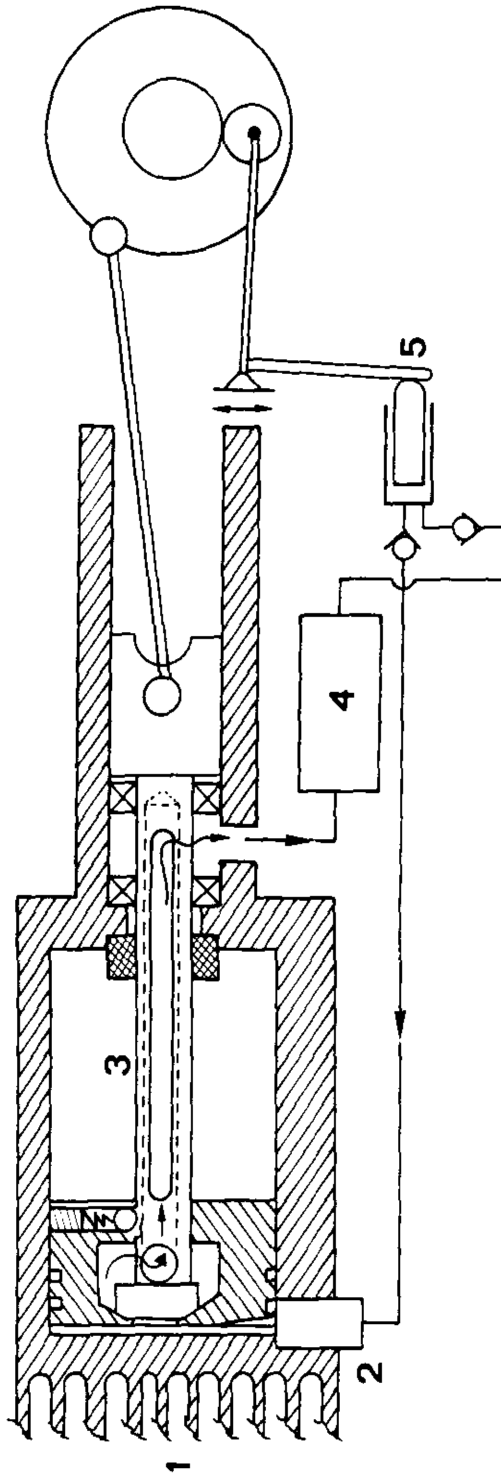


Figure 3 - Layout of the Aisin Seiki NS30A Stirling engine. 1: fuel inlet (CH); 2: air inlet; 3: exhaust outlet; 4: regenerator; 5: water-helium heat exchanger; 6: working piston; 7: helium-exhaust heat exchanger; 8: air-exhaust heat exchanger; 9: swash-plate system. Dimensions are in mm (Source: [1], modified)

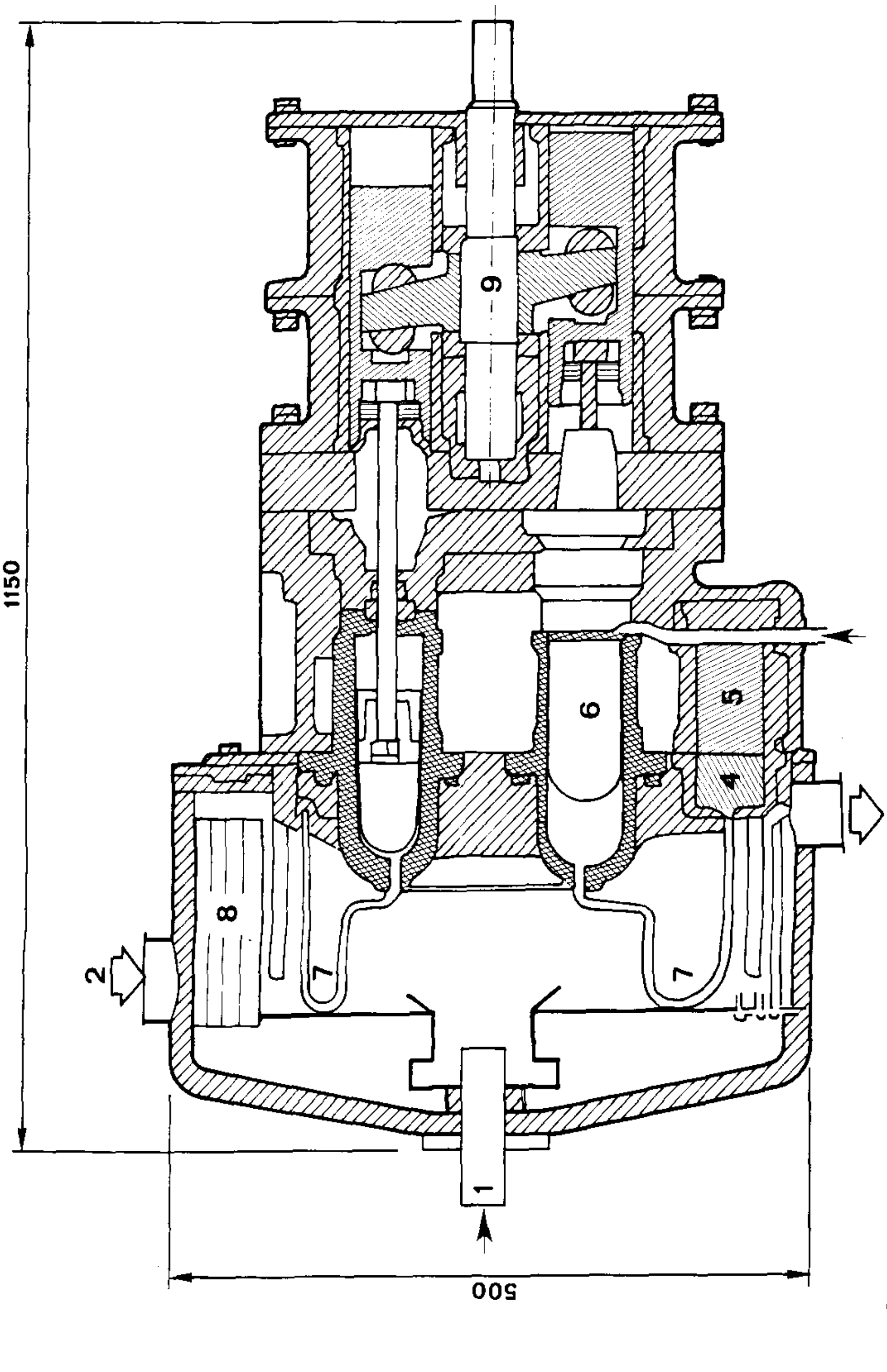


Figure 4 - Aisin Seiki NS30A performances (Source: [l], modified)

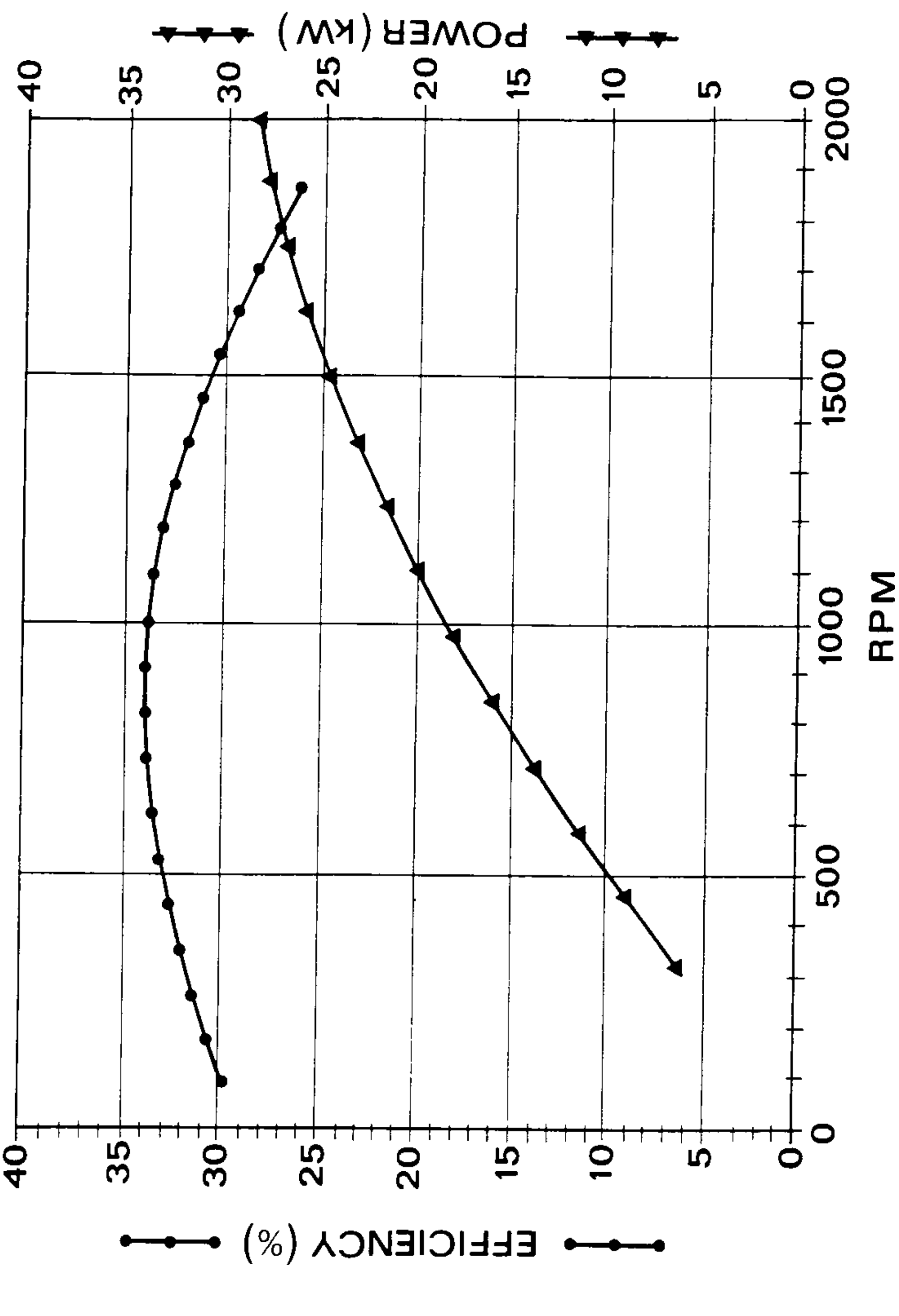


Table 1 - Technical data on some marketed reciprocating steam engines (Source: [4], modified)

MANUFACTURER		MERNAK (BRASIL)	SPILLING (GERMANY)	SKINNER (USA)
Shaft power	(kW)	30-530	100-1800	10-200
Speed	rpm	240	750-1500	300-550
Inlet steam Conditions	(MPa/°C)	1.0-1.4/350	<15/350	0.8-saturated
Exhausts	(MPa)	atmospheric	?	0.10-0.12
Specific Steam Consumption	(kg/kWh)	?	?	40-52
Approx.cost of the engine	($ US/kW - 1987)	1000-1200	1700	520-1000

Table 2 - Some data on reciprocating steam engines under experimentation (Source: [4], modified)

DEVELOPER-YEAR		THERMO ELECTRON CORP.(USA) - 1969	SCIENTIFIC EN. SYSTEMS & RICARDO (USA) - 1974
Application		military 24 V DC generator sets	automotive
Shaft power	(kW)	0.1-1.5	21
Speed	rpm	1800-3600	2000
Inlet steam Conditions	(MPa/°C)	2.0-4.7/420-450	6.8/540
Exhausts	(MPa)	condensing at 0.2	condensing at 0.24
Overall efficiency	(%)	4-8	20 (best)
Basic design		single expansion single acting	single expansion single action converted i.c. engine
Reference		ASAE pap. 690046	ASAE pap. 740296-750068

Table 3 - Four-months average data from some diesel application in Kenia (Source: [10], modified)

ENGINE RATING (kW)	AVERAGE LOAD (kW)	RUN TIME (h/day)	AVERAGE EFFICIENCY (%)	APPLICATION
9	0,9	8.8	10.0	domestic appliances
17	1.8	5.7	8.0	water pumping
25	5.0	5.0	11.3	irrigation pump
48	13.2	6.0	17.8	lighting

Table 4 - Some data on existing Stirling engines.

MAKER		AISIN		GSC		SUNPOWER
Model		NS30A	ISAS200	STM4	V160 (5)	ST5
Working cylinders	(n.)	4	1(free)	4	1	1
Fuels		any liquid		CH_4	CH_4	biomass
Working gas		He	He	He	He	air
Max average pressure (MPa)		12	?	? (2)	15	?
Heater temperature	(°C)	770	750	? (2)	650	?
Cooler media temp.	(°C)	25	60	? (2)	50	?
Max shaft Output	(kW)	30	0,2 (1)	25	8	4
Speed	rpm	2000	?	?	3000	?
Max Efficiency	(%)	37,5	13 (1)	37	25	< 10
Expected life	(h)	30,000	?	?	40,000	20,000
Noise	(dBA)	< 76 at 0,3 m	?	76 (3)	85	?
Weight	(kg)	250	?	350 (4)	240 (4)	?
References		[1]	[1]	[7]	[7]	[11]

(1) referred to the electrical output
(2) similar to the NS30A engine
(3) distance is not declared
(4) with electrical generator
(5) V160 was produced by Stiling Power System USA, now incorporated in GSC (General Stirling Corporation). A Similar engine is produced by Schlaich & Bergermann (D)

Table 5 - State of the art for different reciprocating engines that are used or could be used in agriculture (Source: Institute of Agricultural Engineering, Milan).

CYCLE		DIESEL		STIRLING	RANKINE
Type of engine		nat.aspiration	overcharged	swash-plate	(4)
Specific power	(kW/dm^3)	10-16	16-22	40-60	?
Specific mass	(kg/kW)	7-10	4-6	8-10	?
Speed	(rpm)	1500-3000		1000-3000	500-2000
Efficiency	(%) (1)	30-40	35-45	30-35	6-15
Optimum efficiency	(%) (2)	45-48%		40	20
Useful life	(h)	3000-20000		> 20000	> 20000
Price	(US$/kW)	150-250 (3)		?	?

(1) calculated for I.C. from declared specific consumptions
(2) achieved in large I.C. engines or experimental E.C. engines
(3) small engines (< 10 kW) can exceed 500 US$/kW
(4) converted I.C. engine with condenser

Table 6 - Energy balances for different renewable fuels (Source: Institute of Agricultural Engineering, Milan)

FUEL		ETHANOL (MAIZE)	ETHANOL (WHEAT)	METHIL-ESTER (RAPE)	RAW-OIL (RAPE)
kg of seeds/kg of fuel		2.7	2.7	2.5	2.7
LHV	(MJ/kg)	29	29	38	37
En.balance	(MJ/kg):				
— agriculture		13-14	10-11	14-15	14-15
— processing		13-15	13-15	15-16	7-9
— total		26-29	23-26	29-31	21-24
Yield	(t/ha)	1.8-2.2	1.1-1.3	1.1-1.2	1.1-1.2
Out/In		1.0-1.1	1.1-1.3	1.2-1.3	1.5-1.8

Table 7 - Some emission data. Dual fuel operation with natural gas is extremely pollutant due to low temperatures reached in conventional Diesel engine. In spite of this the use of raw vegetable oil helps to reduce them (Source: Institute of Agricultural Engineering, Milan)

Type of engine		Stationary Diesel Engine (30 kW class)					
Type of fueling		dual-fuel system with direct injection					
Rev./power	(rpm/kW)	1500/0	1500/16	1500/16	1500/24	1500/24	1500/32
Type of fuel (1)		D	D-NG (2)	RVO-NG (2)	D-NG (2)	RVO-NG (2)	D
CO	(ppm)	370-380	2150-2300	1950-2200	1900-1970	1780-2040	220-280
NO_x	(ppm)	120-130	280-320	320-420	510-540	830-860	1200-1270
HC	(ppm)	63	2250-2300	1200-1350	1700-1800	1300-1400	47
Smoke number		0	0	0	0	0	0
CO_2	(% vol.)	1.4	3.2	3.5	5.0	5.0	7.1
O_2	(% vol)	19	13.8	13.8	11.2	10.5	8.9
Exhaust temp.	(°C)	108	260	330	227	330	392

(1) D: Diesel; RVO: raw vegetable oil; RME: rape metil ester; NG: natural gas
(2) flow rates adjusted to obtain 50% of power from NG

Table 8 - Some emission data (Source: Institute of Agricultural Engineering, Milan)

Type of engine		Tractor Diesel Engine (50 kW class)							
Type of fueling		direct injection							
Rev./power	(rpm/kW)	870/0		2350/26		2350/43 (1)		1400/35 (2)	
Type of fuel	(1)	D	RME	D	RME	D	RME	D	RME
CO	(ppm)	160	260	280	160	710	280	2700	1600
NO_x	(ppm)	330	235	590	600	930	1110	1680	1880
HC	(ppm)	21	19	26	13	31	21	22	27
Smoke number		0.1	0	1.9	0.6	2.8	1.2	4.0	1.8
CO_2	(% vol.)	1	1	4.5	4.5	7.0	7.1	8.6	8.5
O_2	(% vol)	18	18	12.5	12.5	8.5	8.4	6.0	6.0
Exhaust temp.	(°C)	85	77	350	310	545	467	485	445

(1) D: Diesel; RME: rape metil ester
(2) maximum power
(3) maximum torque

Table 9 - Possible fields for R&D activities.

OTTO	DIESEL	STIRLING	RANKINE
Re-introduction of two-stroke engines	**5-200 kW engines for raw-oil oper.**	**Environmental impact using conv. fuels**	**Design of engines with simplified boilers**
	Assessing the pot. market for raw-oil engines	**Assessing real applicability and potential market in rural world**	

Environmental and social impact using alternative fuels (I.C. alcohol and vegetable oils)

D.J. WHITE

Thank you very much, Prof. Ortiz-Cañavate, Dr. Hermann and Prof. Riva. I think all the three Speakers have given us much to discuss. It is obvious to us all that the Diesel engine has gained ascendancy in agricultural machines because it has a good power/weight ratio and you obviously don't need the performance that is required of an engine in a car. I'm sure we can have a very good debate as to whether some of these engines, or under what circumstances these other engines, might challenge the position of the Diesel engine. I think that we should now embark on a general discussion of the three papers that we have heard and when you make your points we will give any of the Authors a chance to comment.

Before I throw discussion open to the floor I would like to raise a point with Dr. Hermann, because he threw out a line in talking in this particular direction: he said that in Austria, the price of vegetable oil was comparable to that of Diesel oil and there was a slight look of skepticism on his face when he said that. In the United Kingdom we have done our calculations on this. In the UK, as no doubt in other Countries, there is either no tax or a very small tax on Diesel fuel for agricultural purposes and this of course makes it easy for us to compare agricultural Diesel with competitor fuels. Now the calculations that we did suggested that fuel derived from oilseed (rape) would be three times as expensive as Diesel for agricultural use. So perhaps Mr. Hermann would like to tell us what there is that is very particular about calculations on this in Austria.

H.HERMANN

Austria looked at the problem under the aspect of a total economic project. They started with one of their major economical feet they rest on, which is tourism, and tourism in Austria is bound to the landscape and to the type of farming; many people go there only to live on a small farm still having animals and crops and everything and giving them the feel to be embedded into a family during their vacations into a very good world. Now these farmers need to live from livestock mainly and they produce the grass and everything they need to do that. Now the farmers in the valleys, in the richer areas, took a lot of their work and they are living away because they found that livestock is good and they had the better chances to get more crop as livestock food out of their hectare. Now, to keep the tourism going they had to subsidize those small farmers, so one subsidy was for that purpose. Another subsidy was that there was not enough high-protein livestock food in the country and they had to import it - that was subsidy number two. Small grain production provided overproduction in Austria and it had to be exported into the EC and again this was subsidy number three. So they thought if they provided enough of an industrial-type crop to the richer valley farmers they would go away from the dairy farming and leave that to the mountain farmers. This was the Number 1 Effect they were shooting for. At the time they were growing rape the subsidizing of the livestock food import was going down and growing rape would also minimize the overproduction of small grain, which has to be exported on subsidies. So, when looking at all of that, they found that they could, just by shifting the subsidies, provide the litre of rape seed oil methylester at the same price as Diesel fuel. This was my skeptical look. It is not transferable to many other areas of the EC, but there is enough thinking behind that project to make us aware that there is more than just looking at production cost of one unit of fuel - there is much more involved.

At the same time they said to their farmers: "We guarantee to you from year to year a certain price for rape seed, from 20% of your hectares". And by doing so they felt this would force their farmers into a more natural, more healthy crop sequence. So, introducing another type of crop for maximum 20% of the land, would probably come back more to that 5-crop production and then lower the need to put a lot of fertilizer and herbicide and pesticide into the fields. This was a real big project, which did not just look at "how can I produce one litre of RME?". It has been much more.

D.J. WHITE

I must say it sounds like a very inventive form of economics. Do you know if the price offered by the Government to farmers to grow rape was considerably in excess of the production costs of producing rape? Because this is one of the things that we must remember, i.e. that rape, as with other oilseed crops in the Community, is a heavily subsidized crop. But when I said that in the UK it was uneconomic by a factor of 3, we did in fact allow for the EC subsidy, because I imagine that this is something that will have to go, or decrease, if a GATT agreement is reached. We didn't touch on this morning, but I imagine it would be part of any GATT package.

G. RIVA

I have studied the situation in Austria. Unfortunately I do not have here the relevant material but I remember that the problem is the following: Austria exports seeds to the Eastern countries so the basic problem is to avoid the selling activities to the Eastern Countries. The internal price is more or less that of seeds, that means rape is 3.2-3.4 Austrian shillings - now it is difficult here perhaps to choose a unit but you need now more or less 12 Austrian shillings to 1 US$, so the internal price is 3.2-3.4; selling to the Eastern countries, the price is 1.4 or something like that. So the Government sells at a lower price so it has to give the money to the farmers and hence there was a difference of more or less two-thirds of internal price, then. Now the Austrian farmer gains more money producing vegetable oils because he has a premium, a fixed rate to cultivate - if I remember well, 5,000 shillings per hectare per year - as a gift; then they have also the possibility to use the fuel in the farm without taxes. It is assumed that the cost of the fuels is 8 shillings inside (if you go to the oil well in which you can buy vegetable oils, a typical price is 8.1-8.2 shillings); the real cost of vegetable oils is - I remember it in Italian Lire - from 1,800 to 2,200 Lire per liter. That means more or less three times the price of the oil.

D.J. WHITE

Yes. This checks with the UK calculations.

G.PELLIZZI

It isn't very easy to see in the tables, because there are a lot of items in the tables, but the basic items are: the difference of two shillings per kilogram of seeds, as subsidy, then no taxes on the fuel, a premium on the hectare, then there is a price which is evaluated on the cake (the cake now is evaluated 2.5 Austrian shillings per kilogram, because there is a market). All these things make a good business for the farmer, but the real price, including all the expenses, you can reach 18-20 Austrian shillings per litre, depending on the size.

D.J. WHITE

Obviously it is very important that we know just how uneconomic the use of rape seed oil is compared to untaxed Diesel fuel - because that is our starting point. Let's keep on this theme a bit: is there anyone else who would like to contribute on this issue?

Dr. Yoav SARIG
Israel

I'd like to make a general comment. I have the feeling that we are somewhat missing the point - and I want to follow a little bit the footsteps of Prof. Pellizzi. I think the role of the Club of Bologna is not to just have a podium for another technical session. We have plenty of technical conferences to debate that. And I think we sort-of got into discussions which I don't think are our role. Whether or not to use rape seed or other vegetable oil as a substitution for other fossil oil sources is a political decision only. It is a political decision that we are not here to discuss whether it is valid or not. It's like Prof. Pellizzi said: it's beyond our head. What we should do, and I think the terms of reference of the Club of Bologna is to serve as a group of knowledgeable people, assumably knowledgeable people, that could give some directives to policymakers, to engineers, to research institutes, on where should we put our focus and our efforts in the future. I think the last presentation was probably mostly in line with what I would think because it gave us some food for thought: should we for example give some recommendations to do some research in changing engines to meet the oil, based on the facts, on knowledge, or should we maybe solicit some additional studies that maybe on the other hand would change the oil to fit the existing engines? This is the type of work that I would think would fit the terms of reference of the Club of Bologna, because the outside people that look upon us - hopefully - want to get some concrete recommendations; they are not wishing to listen to us whether to use vegetable oils or not: this decision has been made and we could argue if it is correct or not, but it is definitely a political decision. The point that it is far more costly than existing energy and this has been proven so many times that we don't need another proof to do that. It is well known that it is far more costly.

D.J. WHITE

Can I just reply to that one, because I think you are quite right in saying that it is our job to advise anyone who is interested, including our political masters, as to what the opportunities are for alternative fuels and their use, whether they be for mobile or for stationary engines. But one thing to me is absolutely certain: we must advise them on the basis of all the evidence, not just part of it, and part of that evidence is how economic or uneconomic the alternative fuel is, because that determines when it is likely that these alter-natives will be used. I do not think that you can exclude some of the evidence from consideration, and I think the discussion that we have had between ourselves does illustrate that there is confusion over this matter of the true cost of what that fuel is. We must remember that research can alter those relationships and we have got to ask ourselves: is there research that we can do that will make vegetable oils more competitive per se? And this applies to any of the alternative fuels. So I have to disagree with you, Dr. Sarig: I don't think you can exclude this information.

Ir. Aad JONGEBREUR
Netherlands

I want to say that I agree with Dr. Sarig, because of the fact that as agriculture engineers we must not wait till the crop of oil seeds for biofuels is economic. I think we have to go further on the road if we expect that it will be economic in future, so that we are ready with some applications in engines because, if we wait for the moment that people say "It is economic", l think we will be too late and I think that we as ag-engineers have to deal with engineers' problems and not so much with the economical problems. So, I feel much for the hypothesis of Dr. Sarig.

J. ORTIZ-CAÑAVATE

I feel that this is an interesting subject to deal with here in the Club of Bologna. We mustn't consider only the economical aspects but I think it is very important to consider the environmental aspects of these problem. We can contribute to reducing the amount of CO_2 in the atmosphere by using biomass fuels and this I think also has to be considered because there may be a tax applied for CO_2 production that contributes to the greenhouse effect. I agree that this is a political decision.

Prof. Làzlò LEHOCZKY
Hungary

I think the role of this Club should be to give advice, and if it is accepted, the advice would be to make some research and development, or not, in this item. I would say it's not a new problem. Maybe you remember, Gentlemen, from the literature: in the early 1920's there was a large amount of work done on alternative fuels, several investigations were made with windmills in the early 1920's because after the First World War there was in Europe a terrible economic situation. I think we have a very similar situation. Maybe you remember we had the semi-Diesel engine, which was a wonderful engine for the fish farmers and the lance and tractors - which are forgotten already. In this engine you could use every type of fuel. The question of course is one of economy. After the 1973 price explosion there was so much done in Holland, then all they did is now shut up somewhere and nobody uses the results. In Germany, Braunschweig, the same thing. Also in other places. Wooden chips in Finland, wonderful work done there, at the Helsinki Institute. So I think the question is: should we proceed in this direction or not, because of the problem of technology, the problem of economics, the problem of environment? I think altogether we should not stop our research and development because . tomorrow something can happen which will change the whole situation, and the situation could change in a political sense. So I think we should give the advice not to stop but to do the technical research and development in the next future, also having in mind that probably in the next few years - let's hope - it will not be necessary to use the cheapest solution.

Prof. Osamu KITANI
Japan

From my experience when editing the "Biomass Handbook", the biomass system is very, very complex and we need a very systematic way of research and we need quite elaborate research projects. Also, it depends on the time scale. When we defer to this re-search the thinking of the thirty years beyond, then the research project would be completely different. For the long-term research we need better cooperation with biologists and chemists and we as engineers should concentrate not only on the fuel but also on other types of biomass utilizations, including the industrial and pharmaceutical and also some others. I think in the future, when we consider the possible decrease of fuel oils in about 50 years, then it's quite clear that we need organic matter to replace that fossil resource. We are quite certain that we as engineers have to develop some sort of a new biomass system to replace this fossil resource in the future but the most important thing is to have a very good planning to make the complicated problem very systematic. So I would like to suggest to have this kind of basic planning for biomass technology development.

D.J. WHITE

Thank you, Prof. Kitani. Perhaps with that contribution - there are a lot of things to discuss - we can move off the economic aspect and perhaps what we can agree on, is that research is necessary to close the gap which exists at present and of course with the passage of time we must expect that basic fossil energy prices will rise, and that will also assist in closing the gap. But 1 think that none of us is suggesting that R&D should cease just because the situation is rather uneconomic at present, because if that impression has been gained, I think it is a wrong one.

Now, there are a lot of things to discuss. I somehow feel that perhaps an item that we must touch on, is this matter of burning oils in Diesel engines, either in the raw form or treated in some ways, such as esterification. We've heard that the problem of burning the raw oil is that atomization is not good because of the long-chain molecules, and the result is that the combustion is not complete and we get carbon deposits. Which way do we go? Do we try to improve the atomization, so that engines can burn raw oil, or do we think in terms of treatment? Would anyone like to take up this point?

Prof. Hainz Dieter KUTZBACH
Germany

This is not direct to your question, but there is another option for uses of vegetable oil which has not been mentioned up to now, and that is the use in a mixture with normal mineral oil for heating purposes. For example, with a mixture of 5% we can use all our vegetable oil we can produce in the countries here and there are no technical problems with the normal oil burners for house heating. They can burn this mixture or a mixture up to 10 or 20%, without technical changes, and we have no problems with storage of these mixtures. In this way we can save mineral oil for our normal direct-injection Diesel engines. So to think a little bit about this way, would also be a good alternative for us. To use vegetable oil of course, is not economical now - it is a real political decision - but it saves from CO_2 pollution.

G. PELLIZZI

I have a question for Mr. Hermann. If I understood well your speech you said that while Austria followed the line to esterify the oil to be used in the normal Diesel engine (direct injection), the German way was to try to adapt the machines. Could you tell us some more on this line, please?

H.HERMANN

You know that in our country Elsbett became most famous for his new engine concept and he exerted a lot of pressure on, especially, politicians, to look at his concept as he promised "you produce your oil on the farm and then burn it in your tractor or in your combine". But this is not the solution to a problem which exists now: there are thousands and thousands of engines in the market which need to be fuelled and these engines cannot burn raw vegetable oil. Austria clearly thought about that and decided "we have to take care of the engines being in the market and getting into the market for the next 5-10 years, because which engine manufacturer throws his concept and his tooling away just to switch tomorrow to another engine concept? This is not a short or medium term solution. So firstly (and this is my personal opinion as well), we have to take care of the engines being available". This means to bring the fuel to the engines and think out into the future: is it valuable to provide new engine concepts, probably sacrificing on fuel economy, noise, exhaust gas pollution and all of that, where more and more stringent regulations are coming up? So there is not very much room left for engine designers to take care of everything: pollution of exhaust gases, noise pollution, very good fuel consumption, torque back up and all of these aspects, which have become so important.

B. CHEZE

Just a point on this aspect. When l was working for tropical countries we did some transformation of cotton ginning factories in Africa and now there are six big factories that have been modified for the engines - they are big 600 kW engines - and they run directly with pure cotton oil, without any transformation. So we thought that using pure oil was certainly a very interesting solution. We worked also with John Deere in France, Mr. Hermann, on the aspect of modification of the engines, to use also pure vegetable oil, always considering the interest for tropical countries. I think it is also one of the interesting answers to the CO_2 problem because it is consuming entirely biomass in the engines.

G. RIVA

Coming back to your technical question, i.e. esterified oils or raw oils. It isn't a choice: there are two different fields, in my opinion. For instance in Italy we have 15 Mha of agricultural land. Our Diesel oil consumption is 15 Mt. We can cover all this consumption by converting all the agriculture, but that is not possible: we can think of transforming 1 Mha. You know that from 1 hectare you have 1 t of oil, with one crop per year if you contemplate to cultivate rape or something like that, so from 1 Mha I can produce 1 Mt, that means more or less 6-7% of Italian oil consumption. We can understand that it is impossible to use raw oil because you have to solve problems of transport, you have to use the same tank for different fuels, which is not possible (in this sense I agree with Mr. Hermann), and it is impossible also to convert engines because for instance in Italy we have 25 million vehicles more or less (tractors, cars etc.). So in our countries we have to use esterified oils but the panorama will change totally in developing countries, in which you have no plants, you have no alcohol to esterify the oil, you don't have anything. I think it is a good business to produce a single-cylinder engine, air-cooled, direct injection, for raw oil for these countries. But they are different applications, it is not a matter of choosing, because you are obliged to choose in our countries for esterified oil. Not only: you cannot burn vegetable oils in a drier, it doesn't make sense: because I have a limited quantity, I prefer to use a limited quantity where the oil is more polluting. And where is it more polluting? In engines. So perhaps for drying, I prefer to use more efficiently, oil or coal, or even better, stalks. Not oil. Oil is a very high-quality fuel and a very high-quality fuel is best used in mobile machines.

K.TH. RENIUS

I would like to add another comment on priorities. I think that we have to look for the priority that all kinds of alternate fuels should be applied first for stationary applications, as Dr. Kutzbach also pointed out for the special care of drying; while for tractors and for prime movers, second priority in my opinion. This was a result of some studies made in Weihen-Stephan. My colleagues were there and they recommended it and they include also the straw regarding rape for instance, because we have seen in the figures that the balance of input/output could be increased dramatically if you use also the rape straw (for heating, for instance) and if the price for energy will rise a little bit this will become economic.

Y. KISHIDA

When we discuss about this utilization using the bio-resources we have to think about what is a maximum possibility to use the biomass as fuel because already in many countries they cannot catch up with wheat for the increasing population and they cannot supply enough food. Maybe in the future some country which is a big exporter of grain to another country, maybe if the price of oil will increase they can convert the grain to fuel. But it means more shortage of food.

Then I'd like to get some comments from some researcher. What is the limitation of the energy conversion from biomass to fuel and to what extent can we use the biomass for the energy, especially if we want to continue the agriculture in good style, how can we keep the sustainability of agriculture if everybody in many cases calculate how many tons of biomass we can produce from each hectare? But the land requires some return of organic material into the soil ... I would like to get some comment about this.

D.J. WHITE

Thank you, Mr. Kishida. Yes, you do raise a very important point of course on the sustain-ability of biomass production and of course we are very concerned at the present time with the whole sustainability of agricultural crops, and this is leading people to change their cropping rotation in order to better secure this. Or perhaps one should say that we are going back to what people used to do in terms of crop growing. Is there anyone who would like to take up this particular point?

Your other point related to producing fuel from grain, so presumably you were thinking of ethanol, yes?

Y. KISHIDA

No. For example if the price of oil goes over 40 US$ per gallon, in this case getting the fuel from corn must be a lot more economical. Somebody said that already we have maybe 50 years of fossil oil, in this case maybe after 20-30 years the price of oil will increase sharply. In this case it is possible. But it creates another problem: food problem.

D.J. WHITE

We do need to get around to discussing Prof Pellizzi's document so that we can draw some conclusions. Before we do that, I wonder if we could have a brief discussion on alternative engines - not so much alternative engines perhaps but engines that have been with us in the past. Are we going to see the return of the steam engine in agriculture? Are we going to see this `curiosity', the Stirling engine, actually used in practice? Would anyone like to comment? I think we can have a brief discussion.

H. HERNIANN

I think the less important the weight of an engine for a tractor has been the more important it has become throughout the last years. We know about all those activities going on in soil compaction and all that and what kind of tires and tracks are developed to reduce soil compaction. I feel that if an alternative engine comes to the market it should not exceed the weight of current vehicle engines.

K.TH. RENIUS

I think that, specifically in this field of prime movers, we will not have other engines than Diesel engines in the next generation and power density will still increase, for instance by adding turbocharging with intercoolers. But for Third World applications the situation is quite different and this could perhaps be a subject of discussion: what can be done there?

Dr. Amir U. KHAN
Egypt

Can I make a comment from the point of view of the Third World? I think that, from what we have seen, there is a need for two types of engines in the Third World. One is the stationary application, which could be heavier. Unfortunately, some of the older engines are still going and you hear them "chug-chug-chug". They are all very heavy but they would use multiple fuels, but the research was never continued on those engines so they are not produced anymore. Then on the other side there is the mobile application, whether it is a power tiller or any vehicle or small tractor, and things of this sort. So there is a distinct need for two engines, one very, very simple low-technology.

An essentially a man-engine, originally developed in Europe, has actually mechanized Indian agriculture and it has mechanized irrigation in Egypt. If you go to Egypt, all around you see that engine: 5 HP, single cylinder, very simple, locally produced at a very low cost (around 1,000 pounds right now). So I think there is a distinct need to look at even the existing Diesel engines for that kind of market. You have on one hand a spectrum which we, in the developed countries, have totally forgotten. Who will do it I don't know. I don't see the capabilities in the developing countries to contribute major resources in that area. However, I think that the Club of Bologna could make the recommendation that some of the institutions in the developing countries could also look at that side, ie look at the heavier, low-cost simple engines. With regards to the light mobile, of course that is very comparable to the needs that you have here so any development that comes out of here could certainly be useful to us also.

D.J. WHITE

I'm sure you are right in saying that you need two solutions, one for mobile machines and the other for stationary situations and of course it is very much a matter of appropriate technology, isn't it?

We touched earlier on in this discussion on the use of wood as energy. It has not formed a major part of this meeting but wood is really very important and you have to remember that it is an ideal fuel in many respects because it can be used through gasification to power stationary engines. And, incidentally, it has connotations of helping to provide sustainable agriculture. Trees are very accommodating. The nutrients that trees take up become concentrated in their leaves, and I'm not quite sure what the figure is but I believe I am correct in saying that they return to the soil 80% of the nitrogen that they take up. This is sustainable agriculture, through trees and the use of wood.

I know there are people who would like to speak but we really should move on and examine the document that Prof. Pellizzi has prepared. This document will now be circulated and I suggest we take a few minutes to read it through then, as with this morning, we will go through it paragraph by paragraph so that we can obtain agreement.

It remains for me to thank our three Speakers and in doing that I would also like to thank Prof. Pellizzi, because it should be obvious to all of you that he has put a lot of effort into producing this Summary and without doing that, it wouldn't be possible for us to discuss and to come to some agreement.

SESSION 2

Transfer of Technology in Agriculture

G. PELLIZZI

Ladies and Gentlemen, good morning. We can start our Second Session: Transfer of Technologies in Agriculture. Unfortunately we have not received the report from Mr. Mehta, India, and we have no idea of what happened with him, so we will have only two keynote Speakers, Dr. Zaps from Germany and Dr. Kahn from Egypt.

Before starting I want to inform you that there is a new last edition of Dr. Kahn's report.

The second information I want to give you is that from 4th to 7th April 1995 Prof Kitani will organize an international symposium on "Automation and Robotics in Bioproduction and Processing". This symposium will be sponsored by the Japanese Society of Agricultural Machinery and the CIGR (International Commission of Agricultural Engineering).

The third information is that I want to make few comments on a very interesting book edited by Prof. Kitani and Prof. Hall from the United States. I have seen a copy a few days ago and had a chance to examine it a little bit. It is very interesting and very useful. If you are interested, the title is "Biomass Hand-book", published by Gordon and Bridge Science Publishing, New York.

We can start with Session 2. As you remember, we have asked Dr. A. Rijk, Chief of the Agricultural Engineering Service at FAO, to act as Chairman of this Session. Dr. Rijk you have the floor.

Dr. Adrianus RIJK - Session Chairman

Thank you, Prof. Pellizzi. This morning we have a very interesting topic to discuss: the transfer of technology in agriculture. The Keynote Speakers will present papers on their experience in these developing countries. It is a pity indeed that Mr. Mehta did not come. However, as a result we'll have much more time for the first presentation of the paper and in particular for the discussion.

Transfer of technology may not be so much of a problem in the industrialized countries but in the developing countries it definitely is, as we in FAO and many of you will have experienced from day to day. It is particularly in these countries that we need new technology in order to ensure that sufficient food is available to feed the population in these countries - hunger is still a big problem there, rather than environmental problems and so on. To produce food we need at a minimum, as I always say, "land, seed and farm power", and in particular the latter is often forgotten: we always talk about employment problems and so on but without farm power you don't get any crop produced, harvested or threshed. Farm power may be manual labour, it can also be draft animal technology, but in many cases we will also need mechanical power technology, particularly in the countries where land is not scarce but ample land is available. Therefore, to increase food production we also need farm power mechanization technology, in whatever form it is - pump sets, threshers or tractors.

Introduction of these new technologies in developing countries is a very, very difficult process, as I said earlier. Farmers are often uneducated, extension service is usually very inadequate and the physical infrastructure to supply and maintain the new technology is often not in place and it takes usually a long time to develop all this.

We have two speakers, the first one comes from the private sector and it is particularly very interesting to see how they approach this problem of transfer of technology. Dr. Zaps, may I invite you to present your paper.

Dr. Dietrich ZAPS Klöckner-Humboldt-Deutz AG Germany

TRANSFER OF TECHNOLOGIES IN AGRICULTURE: THE CASE OF DEUTZ IN ALGERIA

The current economic situation Algeria is very difficult; the social conditions in the country are hard as well (**Figure 1**). Foreign debt amounts at present to 25 billion US$. The relevant debt service rate in the amount of 10 billion US$ consumes approximately 75% of Algerian export income.

Algeria has a favourable balance of trade of approximately 3.5 billion US$. The reserves of foreign currencies presently amount to 1.6 billion US$.

Basic food, for example grain, has to be imported and absorbs foreign currency which is badly needed for industrial purposes 8s well.

The yearly increase in population is 3%. Approximately 21% of the employable population is jobless.

7.5 million people, that means 29% of the population, are illiterate; 53% of them are women **(Figure 2**).

After a period of economic liberalization the new legislation of October 1992 subjected the economic policy to a strict austerity, which means a sort of control over foreign currency and a priorization of certain key industries.

Fundamentalists are trying to influence politics by attempts at "Islamization".

The "case of KHD in Algeria" originated 23 years ago and started in 1969 with the agreement to construct an engine and tractor factory in Constantine. This agreement was an element of the Algerian policy of nationalization and industrialization which was initiated by the Government after independence in 1962.

In so far the "case of KHD in Algeria" is part of the various stages of industrialization **(Figure 3).**

What is KHD?

Why is KHD an "ideal" partner for Algeria, for Algerian industry?

Here I explicitly correct myself: not trading partner, but partner for industrialization **(Figure 4).**

KHD is a German industrial enterprise operating in the field of industrial engineering covering three strategic industries important for the industrialization of a country.

Here the interests, i.e. strategies, of KHD and Algeria come together (Figure **5 and 6).**

The construction of the engine and tractor factory was concluded with the start of production in 1974.

Essential elements of this project **(Figure 7**) were:

— transfer of manufacturing technology:
— transfer of product technology;
— extensive training programs in manufacturing methods, management and marketing analysis;
-- quality standards;
— production planning.

Let me take this opportunity to mention that the National Board for the Agricultural Engineering Industry - PMA (Entreprise Nationale de Production de Matériels Agricoles), at the same time as the engine and tractor factory, built a combine factory with the assistance of the German company Claas on the same basis. Further cooperation and licensing of various agricultural engineering products promoted the set-up of an independent agricultural engineering industry in Algeria.

Back to the "Case of KHD in Algeria": two years prior to starting production in the engine and tractor factory the KHD "Industrial Plants" Division signed a contract for the construction of a cement plant.

In the early 1980's studies were conducted on extending the engine and tractor plant because local requirements could not be covered by this new installation.

In the middle of the 1980's the first signs of wear and tear could be seen in the industrial plants. Negotiations started **(Figure 8)** on:

- restructuring of the complexes;
- extension of capacities;
- installing "state-of-the-art" product technologies;
- substantially lower in-plant content in the various complexes, especially with a view to increasingly low budgets;
- harmonization of national capacity requirements of the various stages of net product value;
- inclusion of the German partner in exports;
- training of the Algerian partner in export business, especially for Western Europe.

Recently KHD received an order for planning the lay-out of the plant to meet future requirements. Which criteria of success do we have in a critical analysis or which aims were reached?

Which aims remained a vision and could not be realized up to now?

Concerning the critical analysis/success factor, the related problems are (**Figure 9**):

- lack of planning ability in middle management;

- insufficient maintenance in the plants:
- considerable cost caused by production shutdowns;
- increasing aging process of equipment;
- internationally declining competitiveness; national industries suffer from high production costs;
- low-cost imports are menacing the national industries;
- negative influence on trade balance by drain of hard foreign currency;
- insufficient flexibility in parts supply on account of financial control by the Government;
- non-existing but necessary continuity of supplies;
- lack of national medium-sized supplier industries;
- the national industrial complexes are largely dependent on the original partners' respective countries of origin.

Concerning the Critical analysis/success factors, the related opportunities are (**Figure 10**):

- Algeria has built up the only substantial agricultural engineering industry in the Maghreb area. In the meantime our partner locally manufactured approx. 100,000 tractors. The export of tractors and implements to the Algerian neighbours in the Maghreb area as well as to other African countries is part of this strategic concept. Looking to a long-term strategy of cooperation or industrialization of countries which are much less developed than the North African countries, the Algerian industry could become a "generator", for example, of agricultural engineering adapted to African requirements. Regarding this inter-African exchange of goods, the cultural relationship is playing a major part. Moreover, there are no language problems with these customers, which is an important factor for success in business;
- with this tractor population, a mechanical service network has been set up in Algeria. This is a positive development from the standpoint agricultural engineering as well as for the general economy and means a substantial contribution to industrial development.

Finally, also in relation to the theme of the meeting, it is important to summarize that:

- during the past 30 years Algeria has taken giant strides towards the industrialization of the country. Various industrial branches have been developed in Northern Africa;

- industrialization has also nurtured the level of education and professional training substantially.

Not in all cases efforts were successful to focus priorities to a continued systematic improvement of all processes in the enterprises. There arose temporary standstills and today there is even the danger of a collapse of production systems.

Consequently now - after the start 30 years ago - all efforts of the Algerian partners are focused on stabilizing the existing industrial complexes and increasing their output. The aim is to increase food production with local means so that in spite of population increases the country can cover these requirements from its own resources. Foreign currency can thus be used for the modernization and extension of industry.

The future prospect for these enterprises and countries lies in the following:

— to become the turntable for deliveries to third markets;
— favourable labour costs with tolerable production deficiencies;
— recommendation as good quality suppliers for the industrialized countries.

Figure 1 - Economic situation in Algeria

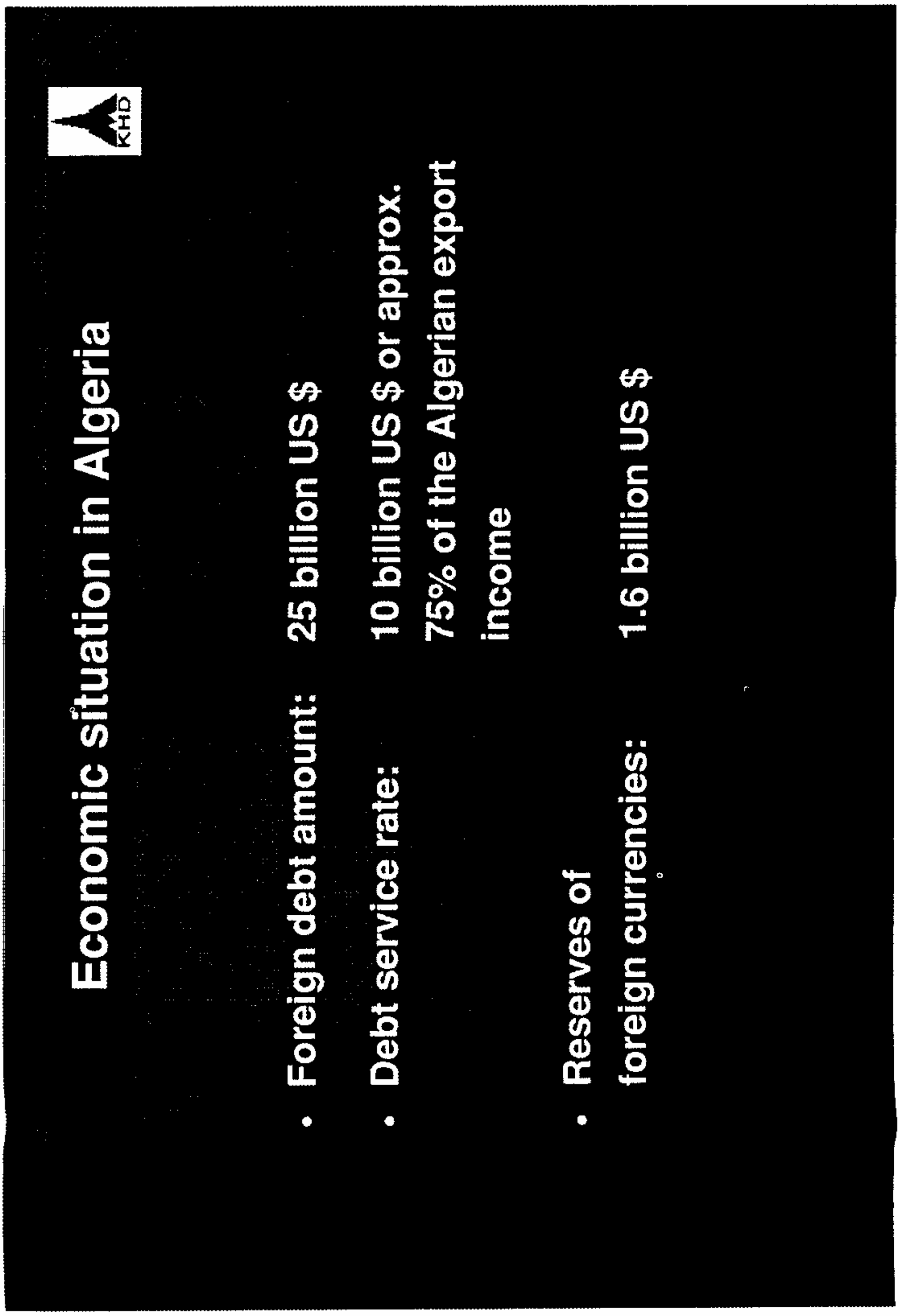


Figure 2 - Social situation in Algeria

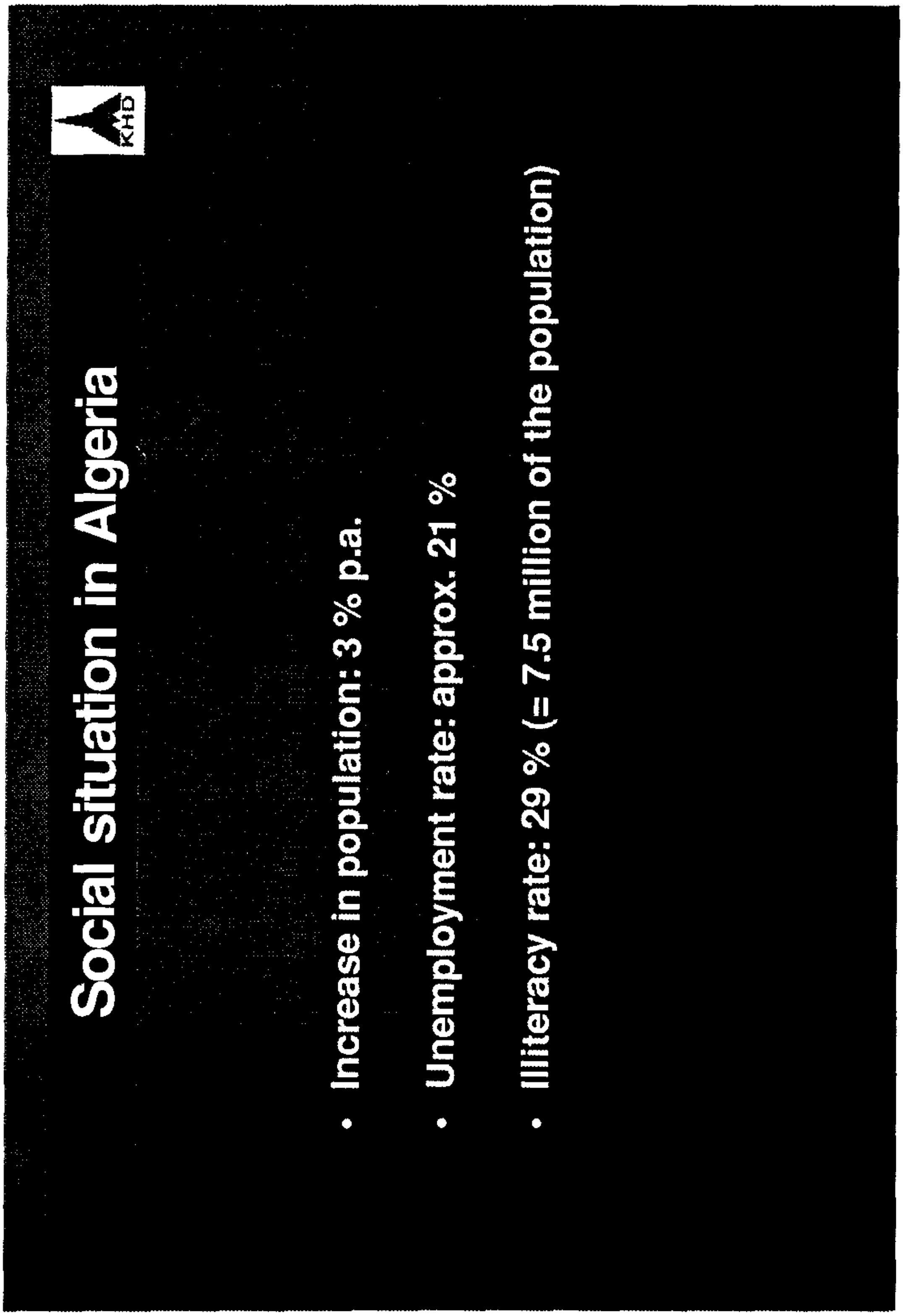


Figure 3 - Stages of industrial development

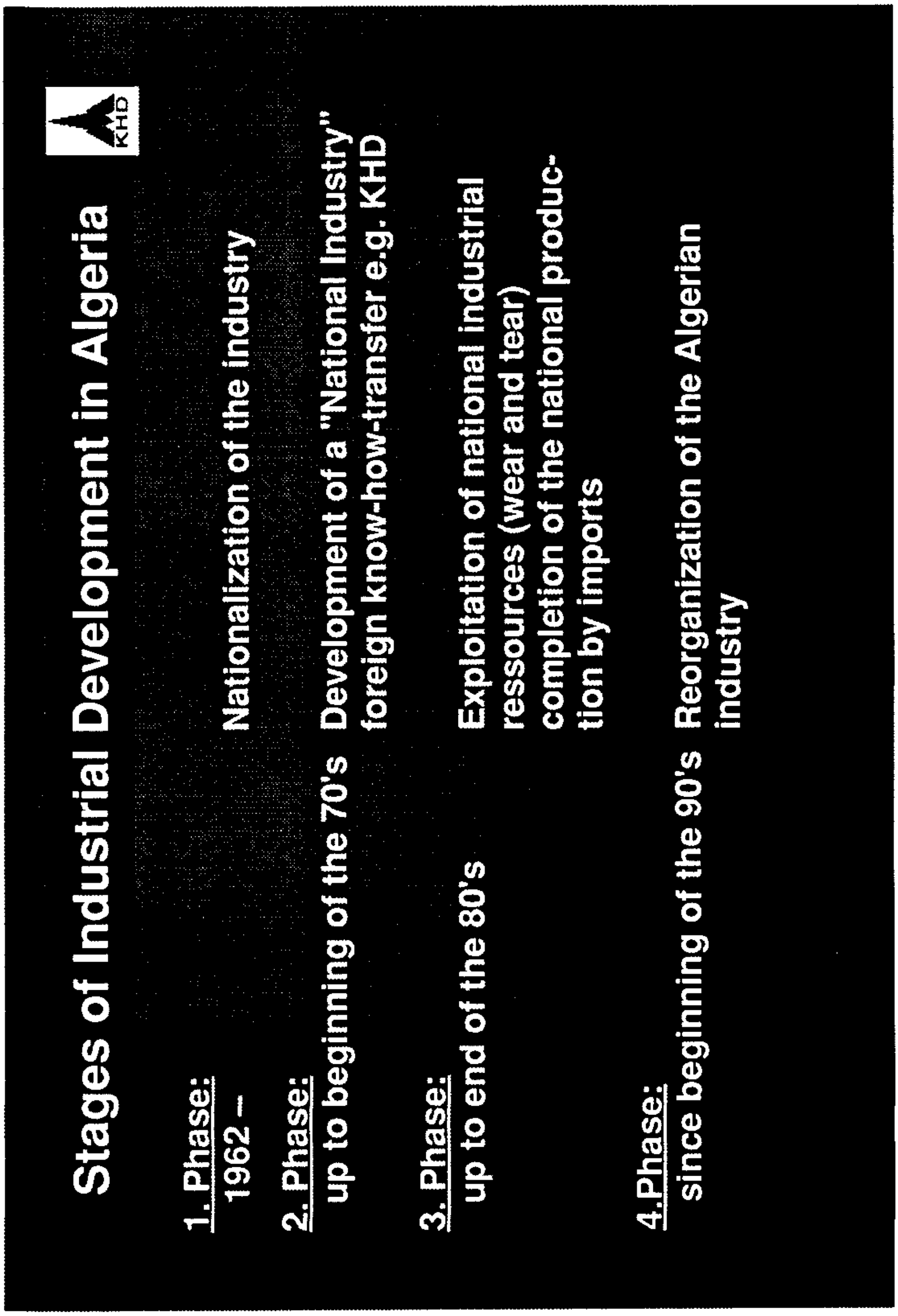


Figure 4 - KHD: Divisions and Key Industries

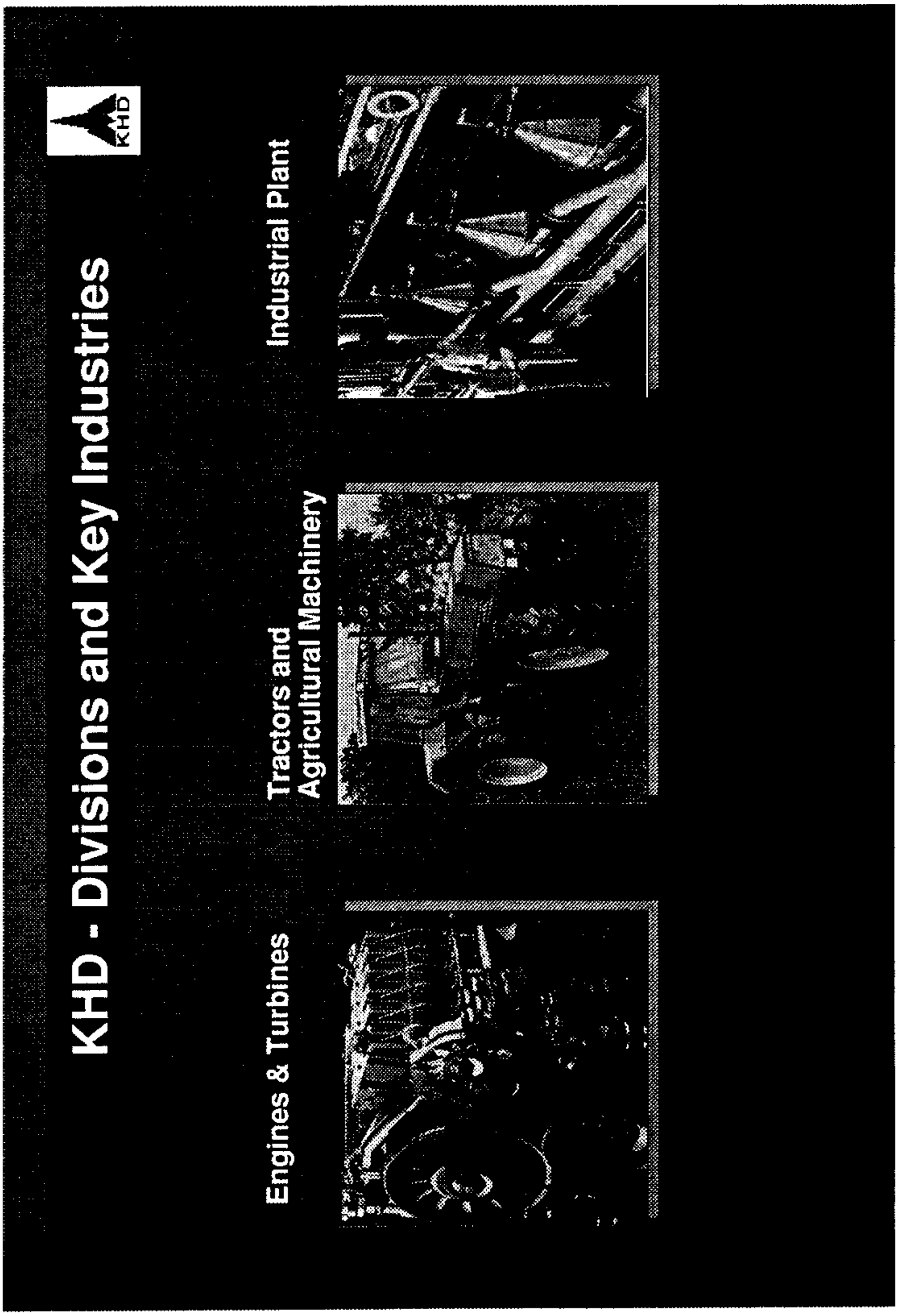


Figure 5 - KHD as Algeria's partner

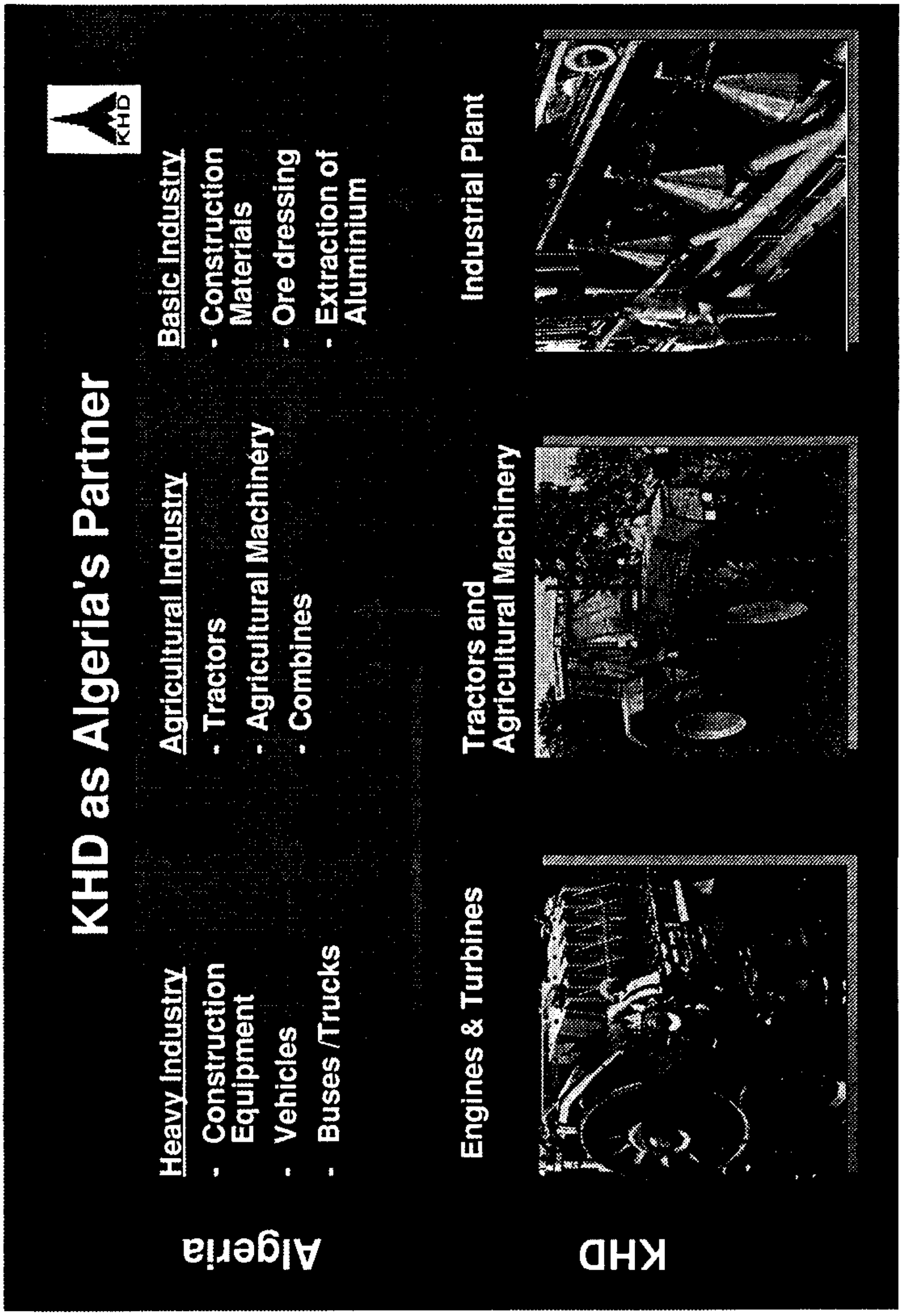


Figure 6 - Engine and tractor factory

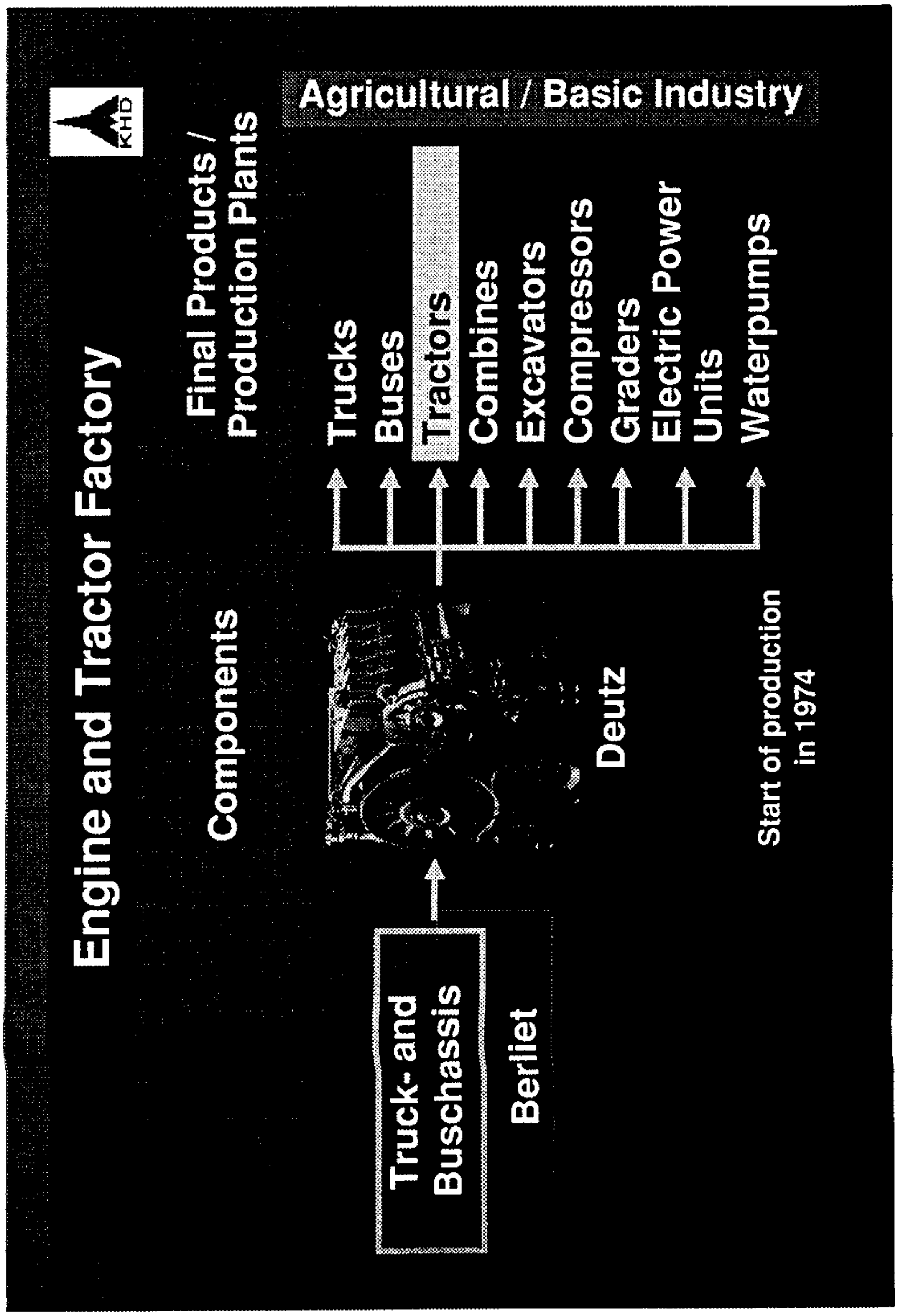


Figure 7 - Essential elements of KHD-Project

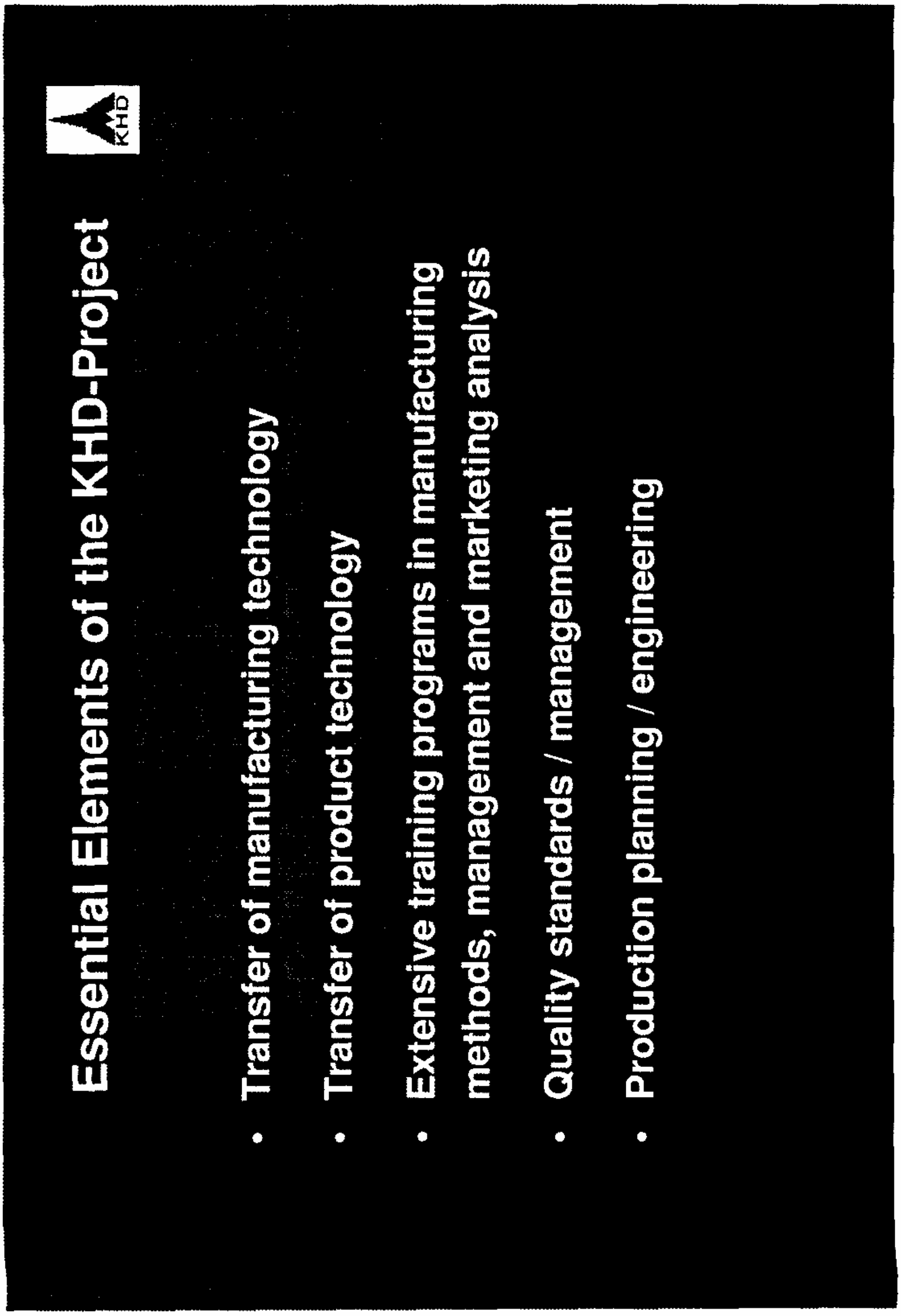


Figure 8 - Restructuring algerian industry

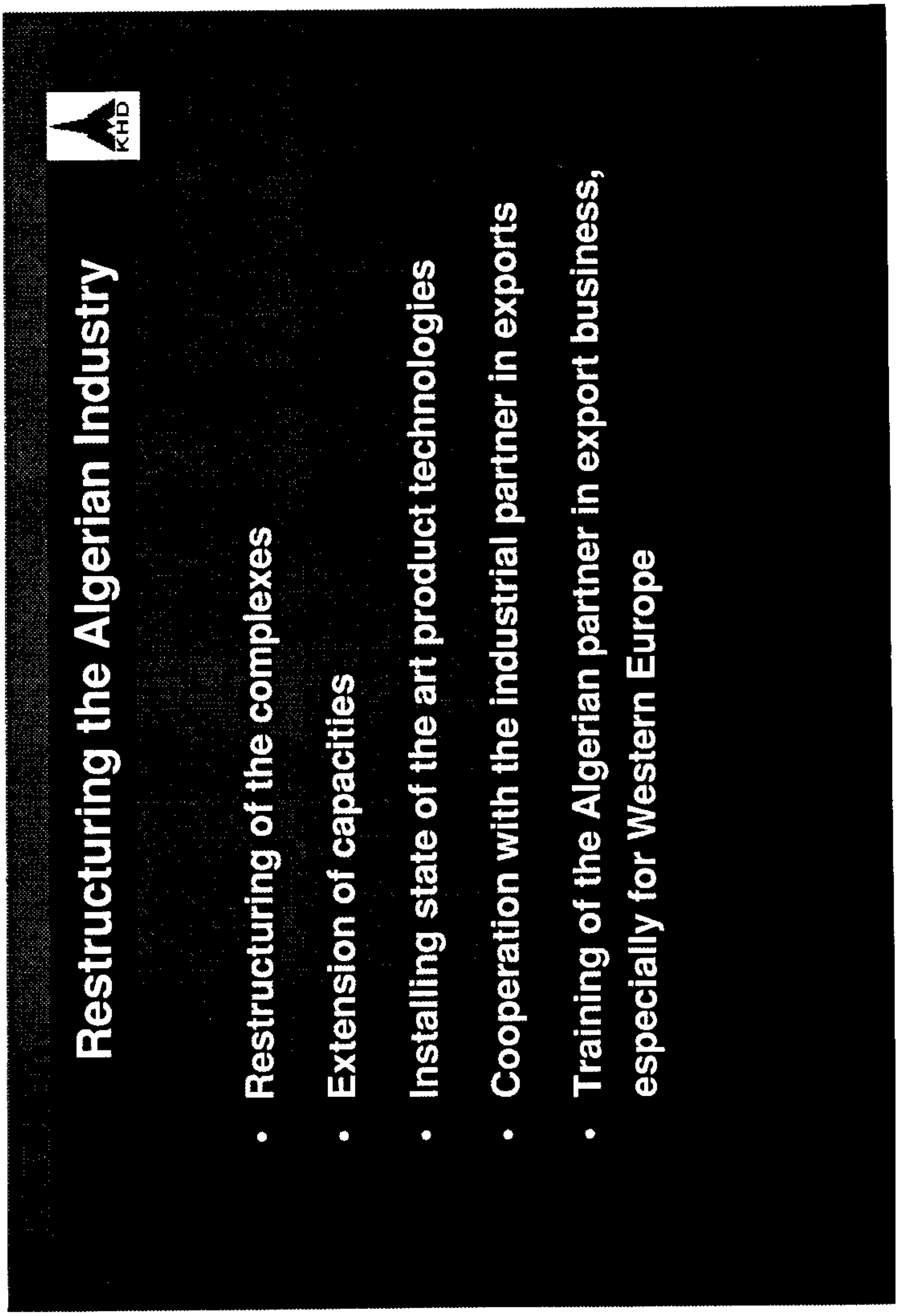


Figure 9 - Critical analysis/success factors

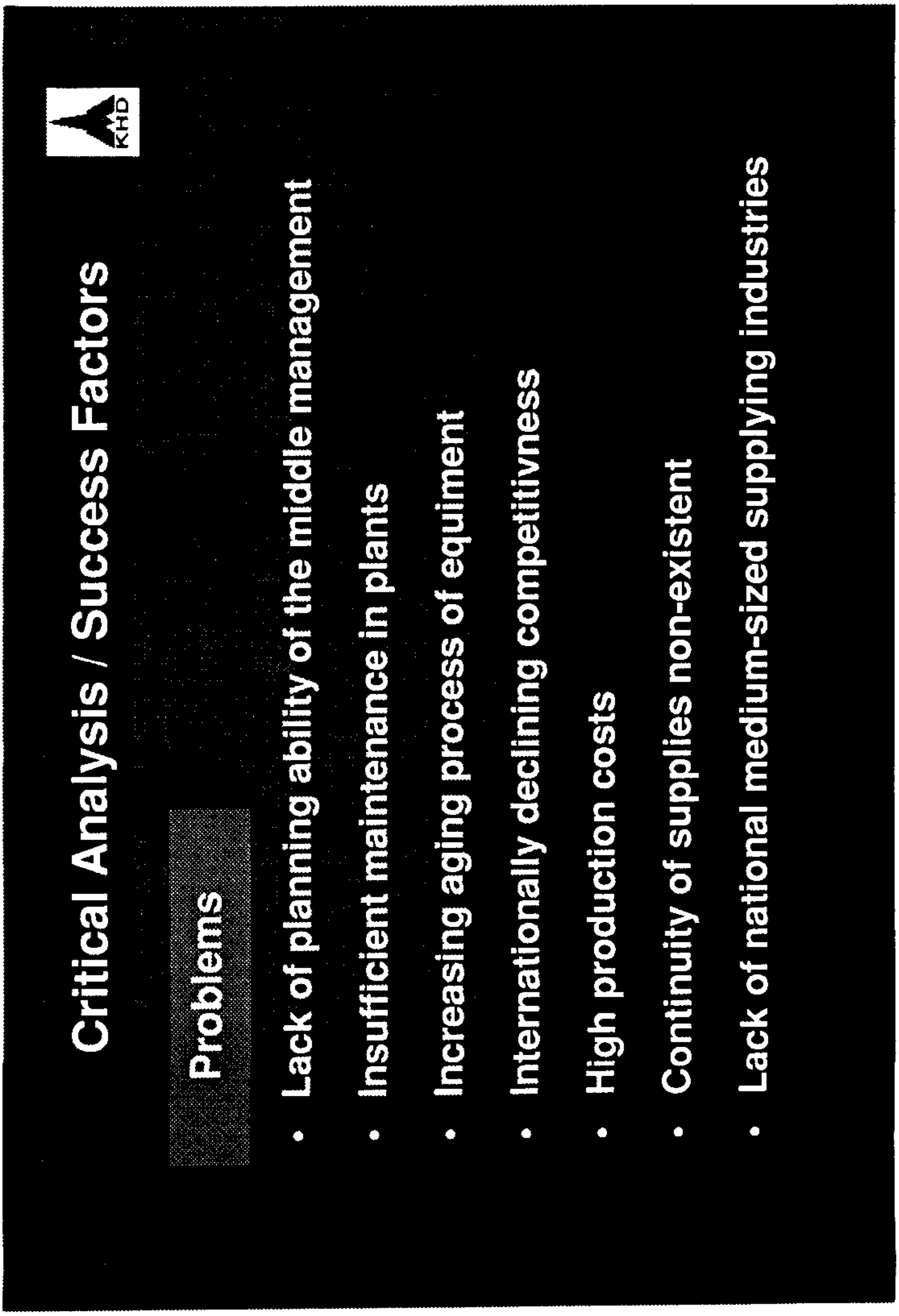
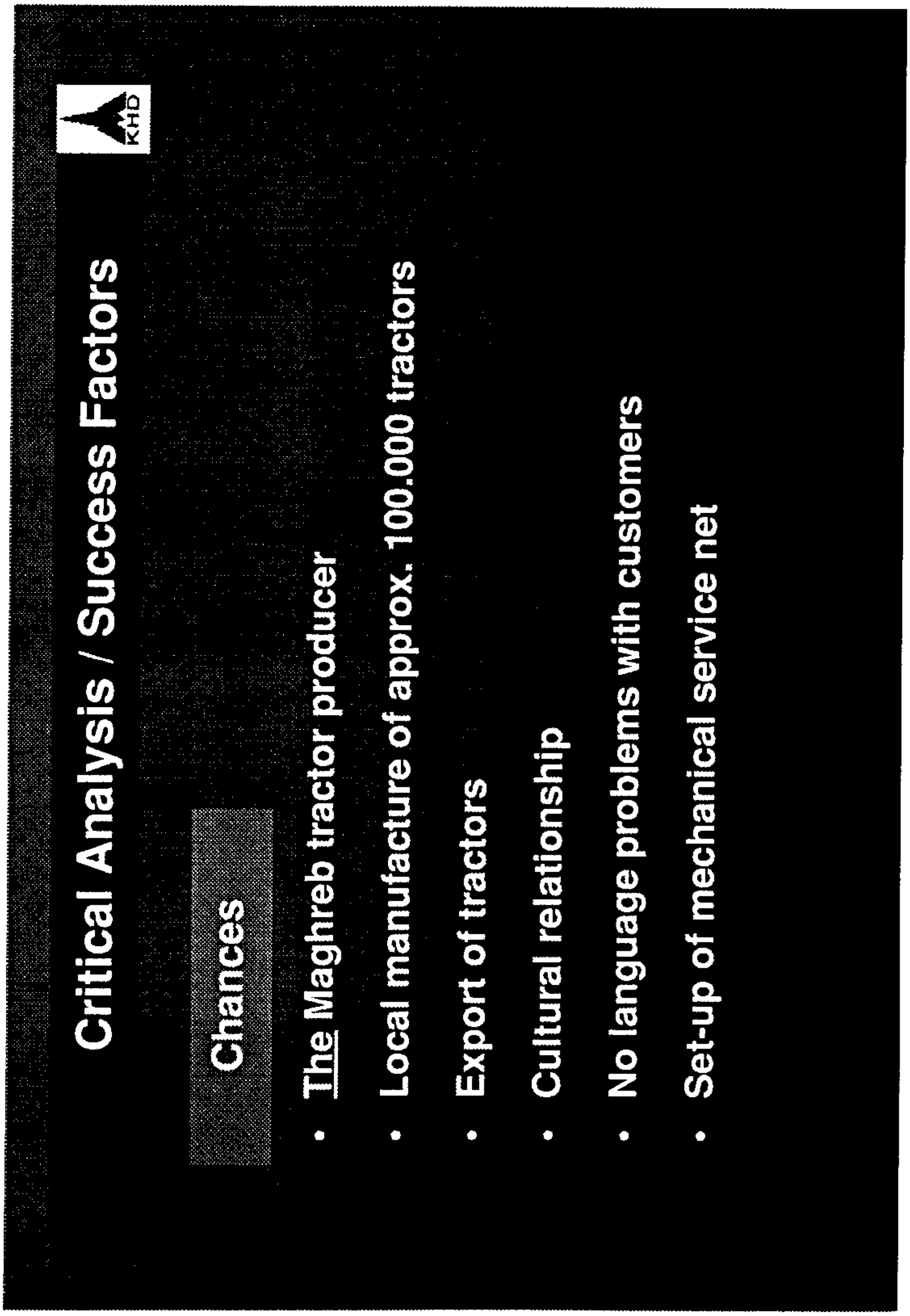


Figure 10 - Critical analysis/success factors



A. RIJK

Thank you, Dr. Zaps, for your presentation. We may now open the floor to questions from the Audience.

A.U. KHAN

I wanted to know what is the percent of "local content" at the present moment, because in Egypt we are running into the same thing, i.e. the companies (they are nationalized companies) claim of producing so many tractors but the fact is that they are essentially assembling. What you said in your introduction - that there was a full 100% local manufacturer objective - we would like to know what you have achieved, how you have achieved it and in what field you have achieved it.

D. ZAPS

As I indicated in my presentation, at the beginning the local content reached 80%, that means at least that the transmissions, the axles, the sheetmetal treatment as well as hydraulics were produced in Algeria. I also indicated that in-between they suffered from maintenance problems and in so far there was a decrease actually up to 50-60%. But the plant equipment, tooling, machining, is prepared to produce transmissions (and you know that this represents 30% of a tractor) on their own, as well as the foundry and hard metal treatment there is also the equipment avail-able and in operation.

G. PELLIZZI

I have two questions for Dr. Zaps. First of all, I should like to know if it may be possible that the tractor produced in Algeria has been a simplified version of the Deutz German tractor, or whether it is at the same level. The second question: you said that there is a problem of training - I mean, there is a problem of all the allied facilities, starting from education. Could you give some more information on this?

D. ZAPS

This tractor design which was licensed at the time was, at that time (beginning of the '70s), the actual design we had also in Western Europe. These are platform tractors without cabs, and these are just in operation. Due to the actual standard of design criteria I would say that the advance we made in Western Europe has not taken place in Algeria, but at least from my point of view, the equipment and the technology is quite OK to have also a productive process in Algeria. I think the slight improvements with the standard design will take place, but there is actually a difference in design, let's say ten years or some-thing like that.

On the question of training, what I indicated is in respect of the process training in the factory. Quite surely this was a new technology for the Algerians and to start up from the bottom to have a factory under operation everybody knows that this is a very hard step and especially not a question of the top management level, but to have the blue-collar workers trained so that they can do a good job and at least produce quality so that the equipment can be in operation in the field is one side; the other side is to build up a service net and that was the target and the commitment at the same time. Algeria is a relatively large country and this was a step in the new century, for the farmers especially, and they also had to be made acquainted with this technology and kind of service. This was an even more difficult question than building up a factory.

G. PELLIZZI

To your knowledge, did the Algerian Govern-ment do something to improve, for instance, the university engineering curriculum or to give the possibility for skilled workers and so on?

D. ZAPS

Let's say the training was a process between the Algerian holdings and industry as well as also the Algerian scientists and the universities. It was an integrated program, and very much supported by the Algerian Government.

Dr. D.H. SUTTON

Could I ask Dr. Zaps to speak a little bit about the other essential component with a tractor, which is the implement industry. Did KHD become involved in promoting manufacture and improvement of implements for the Algerian and Maghreb conditions, or was this left to the local industry?

D. ZAPS

We are not involved in production of these other implements. KHD is delivering the engines for the combines to the combine factories over there but in the middle '70s up to the beginning of the '80s there were teams of our field research in combination with the universities and other implement manufacturers, to improve and to adapt the agricultural process to the equipment. This has taken place. But we played only one role within these teams.

A.M. EL HOSSARY

Can you let us know something about the impact of your project on transfer of technology to the local Algerian industry?

D. ZAPS

This is what I said before: this is one of the points we are a little bit sorry about. The infrastructure did not improve in the sub-component industry - something like medium-size industry. From our point of view, providing the availability in a lack situation - this is the most important point: there is no medium-size industry available to jump into this, to help and to support. But it is not only true with us but also with other major complexes, also with the combines, and this is also not typical for the ag-business but also for the truck and bus industry it is the same.

A.U. KHAN

Could I make a comment? My observation is that where our tractor manufacturing started by centralized economies, in a sense (like Egypt, they planned it in a central tractor factory, in Algeria the same thing happened) the ancillary industry never developed because the whole thing was planned as a self-contained unit. The story *of* India. and I think Pakistan to some extent, is interesting because they went the other way around. In fact, in Pakistan originally there were nationalized companies and they didn't have much as ancillary industries - Miller Tractor was a nationalized company, a monopoly sort of thing, no other tractor development occurred for quite some time, and at that time they were facing this ancillary industry problem. Subsequently, when other companies opened up a tremendous production of components started to go. I think there is some interesting lesson to learn here: when you plan a centralized set-up you do stifle the development of the small industries to some extent. And of course the other part which I have seen, regretfully I say, in Egypt (I don't know what the situation is in Algeria), they created a situation where the manufacturing is planned by the Government, it is almost a monopoly: a ban of tractor imports is almost instituted. As a result no competition develops. I think Egypt is a good case, where 65 HP tractors are produced, yet all tractors are banned from 25 to 80 HP, or for that matter an air-cooled Diesel engine is produced neither from 5 to about 80 HP, but all engines are banned altogether, from 5 to all the way to 100 HP. There are a lot of policy implications which I think have really stifled the development of industries in these countries, and more so for the smaller scale (smaller scale engines, smaller scale vehicles, smaller scale activities). I think this is some-thing for those of us who are involved in Club of Bologna and other institutions. I think we should try to impress on the policymakers that they are really not helping by creating monopolies but they are damaging the long-run situation.

A. RIJK

I think you gave a very good explanation for this, in particular Pakistan and Egypt as examples. Indeed, we have seen this in many countries where this monopoly comes up, supported by the Government in Government factories and it stifles the whole industry.

In Pakistan Miller Tractors, though, I think the situation was somewhat different. I recall that when they started they just assembled the components supplied from many small manufacturers; later on, when they went in for a much bigger, almost 100%, local content, they started machining and so on. Still, many of the components came from other companies, like the wheels, the tires, the gears, the pistons, the piston rings etc. However, many of these companies where it came from were also often government-owned factories. A very interesting study was done two years ago by USA-AID on the agroindustry. One of the things we always were surprised at was that this Massey Ferguson Miller tractor was so cheap compared to the world market price, but when they started to look into these Government-owned suppliers of gears, wheels and whatever, they were all heavily in the red, they were all losing money and every year the Government was pouring money into them, and if you added all that money to what the actual tractor was going to cost, then the price of the tractor was about 80% subsidized by the government. So there is a lot of policy implications, as Dr. Kahn says. It will be interesting to see now what is going to hap-pen in a country like Pakistan, where FIAT had a factory and Massey Ferguson, Ford (Ford closed its plant). With the freeing of the economy and the selling out of these state-owned suppliers of gears and wheels and pistons etc., these companies will have to become efficient and reduce the price of their components, otherwise the private tractor factories will source from someone else.

D.H. SUTTON

Could I just follow that home, and ask Dr. Zaps to give a forecast of what he thinks will happen to the operation from now, given that in October this year the austerity measures of the Government were initiated?

D. ZAPS

My indication is that first of all the equipment industry is one of the key industries which will be supported by the Government, at least because the Algerians have to push the local production in food. They have to do this, according to the figures I showed before. The other point is just that, as Dr. Kahn indicated, they are willing with all their efforts to push the medium size industry and to bring in companies which are going to invest on a slight level, to have this chain - the added-value production. Everything is combined with the financial situation of the country. If they have the potential to stabilize the processes (there is no doubt about it), it's also the way of management, they can follow up. It is critical, there is no doubt about it.

D.H. SUTTON

Could I ask a subsequent question? To what extent has the Government looked at other aspects, ie other farm power sources, and tried to develop those? Have they developed the animal draft sector or does it not exist in Algeria?

D. ZAPS

More or less it doesn't exist anymore. The production system is centralized in big farms and the private sector is more or less out.

Y. KISHIDA

When you started the joint-venture or whatever, to what extent did you change the de-sign of the tractor? I observed in many cases, in many countries, that when they wanted to start the joint venture, my impression is that in many cases they would start without changing the design of the tractor: then in many cases they cannot make good components in that place and they have to rely on the importation of a lot of components from the developed countries. Of course this creates business for the manufacturers that want to establish a company in the developing country, but I think that maybe if we want to start tractor manufacture in some developing country, before that you should change the design of the tractor, which can be produced more easily in that country. Did you do this before *you* started manufacturing, i.e. did you change the design?

A. RIJK

I thought that question was more or less answered when Prof. Pellizzi asked his question: you manufacture a model which is ten years - I wouldn't say "outdated", but an old German model which is not an up-to-date model. But you raised there a very important point, if I may elaborate a bit on it. First of all I think it is very good that you don't manufacture the latest technology. We particularly started realizing this when we visit the shows and see the latest model tractors. What problems we are going to have in the near future in developing countries, with the high level of electronics and all the types of emission controls etc. on these tractors. I mean, even in a car - I had the other day a clogged carburetor in a French-made car, I started opening it as I would have done in the old days, but all sorts of pieces popped out. I very quickly put it back together and drove it back to the original dealer, who has the special tools and whatever. This is really becoming a problem, I foresee, in the next ten years in the developing countries. Fortunately there is still a number of manufacturers which will produce a pretty "solid" old model tractor which with a few spanners you can do a lot of repairs and maybe the future is for a factory like the Deutz one in Algeria: when the European and American tractors become too sophisticated for many African countries the Algerian tractor will still be in demand because it is simple enough to operate, maintain and repair.

I give another example: in Thailand, where there is quite a bit of import of second-hand tractors from the UK and Europe, if you talk to these importers they specify exactly what they want: they don't want the Massey-Ferguson because the Massey-Ferguson in Europe usually has a hydraulic-power shift which is more complicated; they don't want a dry air cleaner but they want the oil bath type filter because it's simpler; they don't want the rotary pump but they want the in-line injection pump because it gives less problems. So they all go for technology which is what we consider not the latest technology but they consider it more appropriate than the latest technology.

Would you still like to give an answer to Mr. Kishida's question...

D. ZAPS

Yes. First of all I agree with you that the actual state-of-the-art tractor is not worthwhile and not possible to do maintenance and to do service on, in these countries, due to the experience of the people. But the question of changing design is due to several factors. You asked about the relation to the kind of production, the question of providing for quality of another standard but not to decrease your reliability. (think that the tractor of this de-sign, 10-15 years ago these tractors were simpler, the challenge to produce a crankshaft or a camshaft hydraulic is easier than these of today's, there were mechanical gears instead of synchronized gears etc. This aspect from our point of view is the right way. We didn't change the design of special items but we reduced the output and the power of the tractors in order to provide for higher reliability and to prevent mistakes in handling. The other aspect is the question whether you would change the design. You spoke about monopoly situations - starting with such monopoly situations as in Algeria we thought at the time (and I think it was right) not to change the design because if there is a breaking down in one production the whole process is stopped and there is nobody who can help if you are not in a position to deliver, from a European or Western partner, at once. This was an aspect, i.e. from the production design, not to change the tractors. The next point is the application to the field. In North Africa, respectively in Morocco and Algeria as well as Tunisia in the North of these countries we have under many points of view similar conditions to Southern Spain and maybe Greece and Italy, and we didn't see the necessity to change the design due to the application elements.

L.LEHOCZKY

Mr. Zaps, may I ask you please what were your experiences on maintenance and repair networks and, secondly, what was the impact of the introduction of your tractors on the farm structures? I don't exactly know how far the Government influence was taking place there.

Secondly, there were always questions on more sophisticated models for Europe and more "primitive" models for some developing countries.

D. ZAPS

Let me start with the question regarding the impact of the Government. I just indicated to you that the private sector is more or less not existing and consequently the farm structure is quite influenced by government politics and we have larger farms, centralized farms, but at least in the '60s there were the first premises from the Governmental side to provide for local equipment production. It was the main topic: the Algerians wanted to be independent. It was not a priority to have a special design; the first priority was to have an independent factory. It was my private opinion, according to my knowledge of the country, that this was not a bad decision and the tractor design, the implement design is more or less suitable to the conditions. At least these tractors and implements, combines as well, were very successful types, for example in Spain in the Sixties, and therefore the design question is not the most imported issue, I think.

Regarding the question of sophisticated or "primitive" design, that's another story from my point of view, because - Dr. Kahn, I wonder whether you agree on it - the education and training level is at least on a minor stage compared to the networks in Western Europe, the States or in Japan - there is no question about it. You gave some ideas about Pakistan. Having air conditioning, you will have another component which reflects on reliability and durability, there is no question about it, if there is no service and maintenance available. This is a key issue I think. I don't want to speak about "primitive", but an "adapted design", according to the production facility, the education of the people, the service capabilities. The distances to cover are 2-3,000 kilometers; it is the same distance there is in Europe from Rome to Stockholm, to bring one part over there. These are the main points to follow up, I think.

A. RIJK

I have just one question which I feel - at least, I didn't pick it up during the presentation but I think it is important in relation to the discussion: what is the annual production of tractors?

D. ZAPS

The capacity of the factory is 10,000 tractors and 15,000 engines (due to the fact that the engines, as I showed on the table and on the charts, are delivered to other industries as well). The actual output of this factory is something like 6,000 tractors per year and 10-11,000 engines per year.

A. RIJK

I think there is probably one of the issues that Dr. Kahn raised earlier: is it really economically viable to have a tractor manufacturer these days producing 6,000 tractors, 100%

local manufacture? I believe the economic viability is these days pretty much higher, probably close to 20,000 or higher.

D. ZAPS

Quite sure. I have no idea of what the economic figures are but that's not a question of economic feasibility study of producing but it's a question of governmental situation.

K.TH. RENIUS

I have also a question regarding these economics: how many years did your company need to come to the breakeven point? Or have you got to that point already? What about the profit of the company? Sometimes in the newspapers you can read that companies make money by licensing but my experience is not the same: mostly it is a very difficult business and it is more helping the country than making a profit. I think this is also an interesting question - what about profit?

D. ZAPS

This is also an interesting question. Quite surely this depends on the stage of the project. Let me give a less sophisticated answer: in between we quite certainly made a profit, there is no doubt about it otherwise we wouldn't have done this, but actually our main topic is also from our point of view and sometimes more or less free-of-charge we are training people to run the process because we are interested in having the factory running, and this sometimes costs a lot of money.

K.TH. RENIUS

Do they import other tractors also, there? Or is 6,000 the total need for the country?

D. ZAPS

The average demand is 12-15,000 and if they don't reach the figure by production then they import if the financial situation allows it.

A.M. EL HOSSARY

You mentioned before that your project received governmental support. What kind of support did you receive from the Government of Algeria?

D. ZAPS

The most important issue regarding this support is that within the competition of the various industries (oil, gas, etc.) the Government is observing that each industry is a top-key industry, because quite sure there are several items or components which have to be imported because of lacks in the sub-supplier industry and there is a question of demand for accountancy.

A.M. EL HOSSARY

I have another question, if you don't mind. You started in 1962 and you are now 30 years in Algeria. I understand that there is a network of maintenance and repairs but you did not reach till now an ideal state. What are the problems facing you? Thirty years is a long time.

D. ZAPS

One of the most important points is the continuity in having educated people on the jobs. One very simple example: in the first years we had trainings for service people in Germany at our facilities and after having gone back to Algeria we saw these service people in middle management and higher management levels, displaying their "Diploma" behind their desk. Very simple problem, but the effect is large because these are not working in the jobs they were trained for.

A. RIJK

But did you then select the wrong people for the training in Germany or, because of the training, people got promoted to these high positions?

D. ZAPS

Both things. After having these experiences we changed the method and carried out the "train the trainer" principle locally.

A.M. EL HOSSARY

Maybe you had a problem in the dealership system. Does it exist?

D. ZAPS

No, that's not a major problem. We have a dealership system both governmental and private.

R.O. HEGG

I had a few short questions on the presentation. You mentioned the international competition, other low-cost producers. I was curious who the other suppliers are for tractors. Also, what is the cost of the tractors, and what percent are exported (maybe you already referred to it) of these 6,000 per year?

D. ZAPS

The exports are a political issue. That's the major item...and the role and the understanding of the Algerians they have in the Maghreb area; also they have some obligations, in my knowledge, to provide for such exports within the Maghreb community. About the cost of the tractor: I'm not in a position to go into detail.

R.O. HEGG

You are not in a position to answer or you don't know?

D. ZAPS

I don't have the actual standard, neither on price or cost.

A.C. WYLIE

Actually my question has been partially answered. When I raised my hand I wanted to change from machines to people, because I think that the technology transfer process is a people-changing process. What I wanted to ask was: you mentioned that one of your advantages today was cultural links with other African countries. What you did at the beginning, or what you are doing now or what you have found successful in introducing the cultural link - the changes, the people changes - between the European manufacturing and the Algerian manufacturing, did you have reasonably good, well-trained counterparts - obviously you didn't because the bridge seems to be missing there, in getting the message across. This obviously has changed. Maybe you can give us a couple of thoughts on that.

D. ZAPS

There are several stages. In the beginning there were more or less, in rough figures, 200-300 engineers in Lukala workers from Köln in Algeria (for two or three years, I don't know). Then this presence was reduced and there came a period that the Algerians wanted to manage the process themselves alone. Then problems arose and actually we have again 20-30 people over there, in the process.

A.C. WYLIE

I ask the question because our experience is bigger and not necessarily in this field. You can bring armies of experts but if you don't have people who have the local know-how and who can transfer it you have nothing.

D. ZAPS

Same experience. The continuity of having the same people over there is very important.

It is not a question of the number but of the "names" of the people.

Prof. Irenilza DE ALENCAR NÄÄS
Brazil

My question goes towards the same subject, about education. A lot of people talk about the need of this education and we feel that in Brazil also we do have to have this chain of education all filled up in order to transfer any kind of technology. So my question would be, knowing this and as you said and presented: which was the percentage of the whole investment in education, especially in training? Let's say three main levels would be: agricultural engineering curriculum, for example, then the technical level and the middle school level.

D. ZAPS

I cannot answer. I don't know. On average we had, at the beginning of the '80s, 100-150 blue-collar workers in the training course, day by day.

I. DE ALENCAR NÄÄS

Was there any major curriculum change? Or did they start the school of ag-engineering, did they prepare engineers?

A. RIJK

What Prof. Alencar Nääs would like to know is not so much how many people you trained but whether there was a change in the educational system and in the engineering education and so on. But I understand you don't have the answer to that, so we should pass on to Dr. Snobar who had already raised his hand earlier.

B.A. SNOBAR

I think no matter what we do towards reducing or simplifying the manufacturing of tractors, two aspects should not be sacrificed. One is safety, the second is research and development. I feel safety should be up to the latest standards, no matter whether it is in developing countries or in developed countries, because human beings are the same all over. Additionally research and development in a particular country should be directed towards adaptation, improvement of local conditions or designing according to the need of people. These two aspects should not be forgotten by those who are manufacturing tractors in the developing countries.

D. ZAPS

I can only give you my intention to the second item, because on the first item there is no doubt about it. To the second item: the question of designing to the various conditions, to the various regions, it's not only a question regarding the developing countries. This is also for example a very good question: is it possible to have one tractor designed for Europe and the States? It is the same question. Quite sure, it is necessary for a producer to have a design which is accepted by the farmer - the farmer in Brazil, the farmer in the States, the farmer in Western Europe. In Western Europe, it is quite a different story to have business in Britain and in Spain. The conditions are different.

Dr. Arturo LARA
Mexico

I have two very simple questions, just for my information. I would like to know if you have some plans for introducing more recent designs or if you have some plans for modernizing the design of a tractor. The second is if you have some records on the utilization of the tractor - how many hours and how well these tractors march, the real conditions in the field.

D. ZAPS

The first question can be answered very easily: there are actually negotiations about more modem designs.

The second question: from 800 to 1,200 hours/ year.

D.H. SUTTON

Could l just make a comment, in fact, and try and make a linkage between some of the discussions yesterday and what we heard this morning? I think we have heard a very interesting and a very honest and frank discussion of a project, the justification for which was probably political rather than technical or economic. Yesterday we heard another example in the case of Austria: decisions being taken for other than purely technical and economic reasons. There was some understand-able concern expressed yesterday in the discussion about how an eminent Club - the Club of Bologna - can in fact influence Governments or politicians when we are talking about technical aspects. I think it is important that we do remember that these are good examples of the way life is and that we as engineers and scientists remember our position in the System. Politicians need options. They have to make the decisions, but they need options. To make those decisions and to take the options they need the facts - because it is most dangerous in this world to make decisions on the basis of false information. I think one of the good things about the Speakers we have heard in the last two days so far, and the discussion, is that we as scientists and engineers are best able to serve the "development" issue, if you like, by ensuring that the politicians have in front of them the facts, and I think open and honest reporting of experience like we have heard today are a jolly good and a very sound way of going on in the future. We should be making decisions, or helping politicians to make decisions, on the basis of known facts, so that we don't justify it by falsifying the figures.

IL HERMANN

Just a couple of comments. One is to the design. We, and I know of others of our competitors, failed in providing technology to the conditions because everyone said "We are not underdeveloped, we do not want outdated equipment". Another aspect was that after a while in failing to get up with local content it was more difficult to get from the origin factory enough parts, a sufficient supply. Then they wanted to be upgraded with the newest product. Now, with the very new products there would be enormous problems; but with the ones like those that Dr. Zaps mentioned, I think there would be the capability to produce. We had cases in Turkey, we had cases in China, where we ran into very similar problems and where it was not a matter of being able to produce parts. In China for instance we have a contract with three factories and an institute. They got all the drawings, they got all the training and when the last cultural revolution started the product was complete, all testing done, but they are still not putting out tractors. In the meantime, because of a supply out of Germany, they wanted the next product. So this is an ongoing process, and you fail and fail.

One aspect is with respect to training of people. We lost people very quickly. We trained an assembly line foreman and within four weeks he was assembly line supervisor and after half a year he was manager of production and then, with that image in his bag, of being trained by John Deere and becoming a manager, he went out as a general manager into another enterprise - he was not capable of doing that, but we had lost a good foreman. There are many problems and if you think you have solved one you run into another one. I am with you, that this is more a political thing. Either you do it, and struggle, and train and train - as Dr. Zaps said - or you do not go into it.

A. RIJK

I think this was a very good additional piece of information. The question I have though is when you mentioned starting off, saying you ran into these people saying "We do not want outdated equipment, we want the latest, state-of-the-art". But are not those saying that usually the Government Officials? Usually when you run into these problems in a country like China etc. which is centrally planned, state-planned (at least at the time that John Deere entered the area it was very much still so), they say "We want the latest technology, the top state-of-the-art technology"; at the same time, as I mentioned earlier, when you go to the dealers in Thailand who import second-hand equipment, they don't want the state-of-the-art technology, they say "Let's get something simpler because that doesn't give us a headache".

H.HERMANN

The closer you come to the people who are working with the machinery, the more success you have to provide machines to the jobs and to the conditions. But in these countries those people don't have the money, regularly. The ones providing the funds for buying machinery are reacting completely differently.

A.U. KHAN

I wanted to make a comment. I think design complexity and low volume production are quite related and l feel if you have simpler designs they are easier to produce while if they are more complex they are more difficult. The problem becomes that government people want very highly complex, more smart, whereas the demand and the need is for some-thing simple. I'll go back to the early attempts in Thailand: there was a whole series of small manufacturers who started using auto-mobile transmissions and all to build up tractors. They don't produce them anymore now but they did create a tremendous market for tractors: subsequently, used tractors started to come in and fill the gap. So I think the issue raised by Mr. Kishida and many others here, that design is another issue where simplification of design and sticking to that simple design for quite a few years till the market develops is an essential element in moving. I think that while there may be pressures to upgrade and modernize, if you can't make a go with a simpler design you are going to have big trouble in going through with a, more complex design.

A.C. WYLIE

I think of the fact that engineers or technical people never like the fact that the technology is the easiest part of the process being put up front. But really in technology transfer and this kind of things I think the cultural and the political problems will be the ones which will either produce or negate an effect. The technology itself - the "nuts and bolts" - is easy once you've worked out the politics and the cultural factors.

As far as design goes, and simplicity, a lot of the time the home-base offices are the ones that are responsible for tempting the farmer or the user to upgrade, because they come and say: "Hey, this is old! You have to move with something better!" - and these are the central headquarters' salesmen or managers, who come up to visit the local representatives in developing countries.

It is a complex and very intricate system, whichever way you want to look at it.

A. RIJK

If there are no other questions l think we should close. On behalf of the Club we thank you very much Dr. Zaps for your presentation and wish you a good journey home.

The next Speaker hardly needs an introduction: Dr. Amir U. Kahn is well-known from his work in Asia with IRRI, his work at the moment in Egypt under the US-AID project, employed by the Winrock Foundation. For the topic we are addressing, i.e. technology transfer, we are going to have a Speaker now who has done it, who has proven it in the past: he has developed equipment for the small farmers, in particular the axial flow thresher, which has been sold in very large quantities very successfully in Asia. He has received a number of awards for that and for his work and his assistance to the agricultural sector in the developing countries. Dr. Kahn has also produced two papers and definitely I believe the first on transferring agricultural mechanization technology through machinery manufacturers - I glanced quickly through it yesterday - is very interesting, although I understand the presentation he is going to do now is on development and commercialization of the thresher in Egypt.

A.U. KHAN

I wanted to say that - as Prof. Pellizzi said that you can throw away the first paper - I wrote the first paper from my heart, the second one I wrote from my mind, so I think you have to read that before you throw it away. There are lots of concepts in it - I am quite concerned about the productivity of research, the relevance of research and the utility of research coming out of the Research Institutions in the developing countries and with that focus in mind I had written that paper: how it could be improved, what we could do to get some more productivity from them. So I would certainly make a plea that, please, do read the paper. I will be happy to respond if you ever have any questions and write to me on that.

Amir U. KHAN
National Agricultural Research Project,
Ministry of Agriculture
Egypt

DEVELOPMENT AND COMMERCIALIZATION OF ALL-CROP DUAL MODE THRESHER IN EGYPT

1. Introduction

Widespread acceptance of mechanical threshers for wheat and continued threshing of paddy with traditional methods is an interesting phenomenon common to many developing countries where farmers grow wheat and paddy in rotation. In such countries tenderized wheat straw, popularly known as "Tibin" in Egypt and "Bhossa" in India and Pakistan, is widely used as animal fodder.

Because of the fodder making requirements, special beater type wheat threshers, which shred and the tenderize straw, are used in these countries. The beater type machines, however, cannot be used for threshing crops which have fibrous straw or tough cobs, such as paddy, sunflower, sorghum, etc.. Such crops can be threshed with conventional or axial flow type threshers, but these machines cannot make fodder when threshing wheat. Consequently farmers in many developing countries do not have access to a single threshing machine which could be used to thresh all the crops that they grow.

Farmers generally cultivate wheat and paddy in rotation and cannot afford separate threshers for these two major crops. Since threshing of wheat and tenderizing of straw requires much power, mechanical threshing of wheat with beater-type threshers has gained much popularity. Some of the other crops, such as paddy, sunflower and sorghum cannot be threshed with beater-type machines and hence continue to be threshed manually or by treading under animals or tractors.

2. Type of threshers in developing countries

All threshers have a long cylindrical shaped threshing drum with series of pegs, knives or rasp bars attached to its surface. The threshing drum is mounted on bearings and rotates in a perforated trough-like member called the "concave". During threshing, crop is fed between the threshing drum and the concave where it is subjected to high impact and frictional forces to detach grain from panicles. There are three major types of threshers **Figure 1** used in the developing countries:

— Conventional;
— Beater;
— Axial-flow.

Movement of grain and straw in these three types of threshers follows a slightly different path.

The conventional type of threshers were originally developed during the last century. In these machines, rasp-bar or peg-tooth type threshing drums are popularly used. The concave covers only part of the threshing drum, usually a 90 to 120 degree arc. During threshing, crop enters on one side of the concave and passes once between the concave and the threshing drum. During this single pass, most of the grain is threshed and approx. 50 to 70% of the grain is separated from straw through the small perforations in the concave. The rest of the grain is ejected with the straw, which is then separated by large bulky straw walkers and air-screen cleaners. These threshers can thresh a wide range of crops, but cannot tenderize wheat straw for fodder. Because of this shortcoming, these thresher have generally not been accepted in the developing countries.

The beater type of threshers are similar to "hammermills" in design. The threshing drum has beater type knives and rotates in an enclosed chamber with the lower part of the chamber forming a perforated concave. There is no outlet in the concave for ejecting straw. During operation, the straw is shredded and tenderized by the action of the beater knives until it becomes small enough to pass with the grain through the small concave perforations. These threshers were originally developed in India for simultaneous threshing and fodder making from crops such as wheat. These machines are now popular in Egypt, India, Pakistan, Turkey, Iran etc. where wheat straw is used as fodder. These threshers cannot thresh crops with tough straw or cobs such as paddy, sunflower, sorghum etc.

The axial flow type of threshers were originally developed at the International Rice Research Institute in the Philippines and can be used for threshing a very wide variety of crops. In these threshers, crop moves spirally, for five to seven turns, between the threshing drum and the full circle concave. All of the grain is separated from the straw through the concave perforations. Straw is retained by the concave and is finally ejected through a large straw outlet at one end of the threshing drum. These machines cannot make fodder from wheat straw and hence have gained popularity mostly in the wet tropics, where paddy is the main crop.

3. Historical development of threshers in Egypt

During the sixties, simple tractor PTO powered beater-type threshing drums, popularly known as "Balaadi" threshers, **(Figure 2**) had gained popularity for threshing wheat. These threshers essentially consisted of a covered threshing drum with a concave. Crop was fed through a feed opening in the cover and threshed grain mixed with tenderized straw was ejected through the concave perforations and had to be separated manually. These machines were very simple, low cost and *easy* to fabricate locally.

About ten years ago, some firms imported wheat threshers from Turkey. The Turkish wheat threshers (**Figure 3**) had beater-type threshing drums, similar to those of the "Balaadi" threshers, and had built in air-screen separating and cleaning system. The Turkish threshers gained rapid popularity in Egypt and are now being locally manufactured by many firms.

The main reason for the rapid popularly of the Turkish wheat threshers was their capacity to make good tibin and to separate and clean grain from tibin. The Turkish wheat threshers, however, can be used for threshing only three major cereal crops: wheat, barley and beans. Threshing of the other crops (paddy, sorghum, sunflower etc.) is done by treading under animals or tractors which is still a problem for Egyptian farmers.

4. The dual mode concept

Numerous attempts have been made in the developing countries to incorporate fodder making features in conventional as well as axial flow type threshers by installing different kind of straw chopping and bruising devices. These attempts however, have not produced satisfactory quality fodder, as the straw and more specifically the nodes are not sufficiently tenderized. Fodder is normally made by subjecting straw to a high degree of impact and friction, which completely shatters and tenderizes the stems and nodes. The beater type threshers function like a combination thresher-hammer mill by retaining straw in the machine until it is sufficiently pulverized to pass through the small concave perforations.

Some years ago, a dual-mode threshing concept, for convertible beater and axial flow operations, was experimentally tried by the author in the development of a multi-crop thresher in Pakistan. In this approach, the machine was designed such that by resetting some of the machine components, the threshing drum-concave assembly could be quickly converted from a beater to an axial flow type, thus retaining all of the good features of the two types of machines.

A survey of Egyptian farmers and manufacturers in 1988 indicated that they would prefer a modified Turkish type wheat thresher for dual-mode operations rather than a completely new all-crop threshing machine. Such an approach would make use of the existing threshers that are already popular in Egypt and would facilitate rapid introduction and commercialization of the improved machine. On the basis of this survey, a number of thresher development and adaptation projects were initiated by the Agriculture Engineering Research Institute in Egypt. This paper describes the project on converting the Turkish wheat thresher for dual mode operation.

5. Dual-mode conversion of the Turkish threshers

The following modifications where carried out in the Turkish wheat thresher to incorporate the convertible dual-mode threshing features (**Figure 4**):

— installation of a set of louvers inside the threshing drum cover (Figure 5) such that these could be set at 90 degrees with the drum axis for threshing wheat in the beater mode or at 75 degrees with the drum axis for threshing paddy, sunflower, sorghum, etc. in the axial flow mode;

— installation of a hinged cover for partially closing the full width feed opening to permit feeding at only one end of the threshing drum while threshing in the axial-flow mode;

- providing an straw outlet in the drum cover, at the opposite end from the axial flow feed opening, with a door to permit closing of the straw outlet when threshing in the beater mode;

– installation of 4 straw thrower paddles on the threshing drum in alignment with the straw outlet.

With the above modifications, the machine could be converted quickly from a beater to an axial mode in the following three steps:

— changing the drum cover louver angle from 90 degree to 75 degree with the threshing drum axis;

— opening the straw thrower outlet.

— closing the partial feed cover to restrict feeding at one end of the threshing drum.

6. Tests and commercial productions

Three Egyptian manufacturers of Turkish threshers were selected by AERI for cooperative development of the all-crop dual mode thresher. Work was initiated during the 1989 paddy season on modifying the Turkish threshers made by Tanta Motor Co., Gabr & Co. and Mabrouk Brother's Co. The manufacturers fabricated their prototype dual-mode units with instructions and drawings provided by AERI. These machines were tested on dwarf paddy varieties and improved till satisfactory performance was achieved. The machines demonstrated paddy threshing output of 700 to 900 kWh, cleaning efficiencies of 97.6 to 99.88% and grain losses of 1.23 to 1.507% during these tests.

The three firms started commercial production of their machines in 1990 and were able to market over 500 modified Turkish threshers during the paddy harvest season. Subsequently, some farmers started to complain that the dual-mode machines were not performing as well with tall traditional paddy varieties or with excessively wet crops. Further development work was conducted by AERI during the 1991 paddy season to overcome these problems. A new modified threshing drum cover was developed, which exhibited better performance with tall and wet paddy and this design is now being manufactured by local manufacturers. A number of additional manufacturers have seen the dual-mode machines in operation **(Figure 6).**

Much excitement has been generated in Egypt by the conversion of the Turkish wheat threshers for paddy, as many unsuccessful attempts had been made in the past in Egypt and worldwide to adapt beater type threshers for paddy. Many Egyptian farmers are now purchasing the dual-mode thresher or bringing their older Turkish threshers to manufacturers for conversion to dual-mode operations.

With the dual-mode all-crop thresher, farmers in most developing countries can now thresh all their crops with a single machine. In countries such as India, Pakistan, Turkey, Bangladesh etc., where wheat straw is used as fodder, the dual-mode threshing machines offer a good potential for meeting the threshing requirements of a wide range of crops.

7. Lessons learnt

The experience gained with the development and rapid commercialization of the dual-mode threshers in Egypt points to three important lessons for public research institutions engaged in machinery development in the developing countries.

First: It is important to thoroughly assess farmers' and manufactures' needs, preferences and demands before embarking on any machinery development program. For example, our 1988 survey of farmers and manufacturers told us that there was considerable interest in all-crop threshers however, they prefer a modified all-crop version of the Turkish thresher rather than a completely new all-crop threshing machine. Without this understanding, we would perhaps have focused on developing a complete new all-crop thresher which would have been difficult to introduce commercially.

Second: There is no alternative to extensive testing of machines under realistic conditions for successful commercialization of new machines.

Our tests during the 1989 rice season, were limited only to dwarf paddy varieties. Commercial production was initiated a little pre-maturely, before the machines could be tested on other paddy varieties and under different crop conditions. This resulted in a set-back to the program when farmers started complaining about the low threshing output with tall and wet crops. Fortunately we were able to react quickly to solve the problem, before any serious damage was done to the machine's reputation.

Third: Development of the thresher in close cooperation with manufacturers helped not only in facilitating the design and development process but also in expediting commercialization. This cooperation also provided an excellent mechanism for greater interaction between the institutional engineers and the manufacturers' staffs. Most of our engineers gained a wealth of practical knowledge and understanding of manufacturers' problems and constraints. The manufacturers contributed immensely to the project and became fully committed to it as they considered the machine to be their own.

On the basis of a life-long experience in commercializing new machines in the developing countries, the following steps could be recommended for improving the utilization of the R&D work going on in public research institutions in the developing countries.

8. Recommendations for successful commercialization

Wherever possible, improve existing machines and avoid reinventing the wheel.

Develop new machines that are evolutionary in design as these are easier to commercialize than revolutionary machines which may require major changes in farming systems or practices.

As far as possible use only those imported components that are already available in the local market to avoid special imports of components.

Keep a close assessment of the end-product costs during the development stage. It is difficult to reduce product cost after the design has been finalized.

As far as possible, finalize the design on the drawing board. It is cheaper to modify on paper than on the prototype machine. Lack of adequate drawings invariably results in project delays and increased costs.

Develop close day-to-day contacts with farmers and manufacturers to gain better understanding of their problems and to assess their needs and demands realistically.

As far as possible, consult and involve manufacturers early during the planning and development stages of a machinery development project.

Listen more carefully to farmers' and manufacturers' comments and suggestions and place less emphasis on comments from non-users or others who may have insufficient understanding of the practical field problems.

Focus mostly on solving the field problems which are being reported repeatedly. Do not waste too much time on stray problems and suggestions that may be imaginary.

Adopt designs to suit manufacturers production facilities and preferences.

Give appropriate credits to manufacturers for their contributions and make the manufacturers feel they are equal partners in the machinery development and commercialization effort.

Avoid premature release of designs. Thorough testing under realistic farming conditions is absolutely essential for successful commercialization of newly developed machines.

Purchase a few prototype machines from cooperating manufacturers to minimize their initial risk and use these for extensive field testing, evaluation and demonstrations in the potential marketing area.

Convince manufacturers about the merits of the machine and its long range market potential. Obtain their commitment to undertake regular commercial production rather than merely supplying a few machines that you may be ordering.

Encourage manufacturers to undertake test production and marketing of a limited number of machines for at least one cropping season. Never encourage quantity production during the introductory period as machines invariable undergo design improvements and modifications during this stage.

Negotiate realistic prices for prototype machines from manufacturers. Experience indicates that manufacturers usually relate a ma-chine's final selling price to the initial prototype machine price. Negotiating an excessively low price for the prototype, however, may result in the manufactures' losing interest or abandoning the project.

During the introductory stage arrange a few machinery tests and demonstrations in the markets served by the cooperating manufacturers and direct potential buyers to him.

In order to develop a sustained market, encourage manufacturers to sell directly to farmers rather than depending on occasional sales through government tenders.

9. Conclusions

Commercialization of institutionally developed farm machines is a challenging problem in most developing countries. The two most significant strategies that public research institutions could adopt to overcome this problems are:

— careful assessment of farmers and manufacturers needs and demands before initiating design and development;
— thorough testing and evaluation of the machine under realistic farm conditions during the post design stage.

Without question, these are the two key essentials to success in machinery development and commercialization.

Public research institutions must recognize the significant role that machinery manufacturers play in transferring technology to farmers. Such institutions must look towards machinery manufacturers as genuine partners in extending and delivering technology to the end users. Every effort must be made to improve linkages between public machinery research institutions and manufacturers. The practice of cooperative development of machines, in which both the research institution_ and the manufacturer contribute resources. is an effective method for successful technology development and transfer. Without active cooperation between research institutions and manufacturers, it is doubtful whether farm level utilization of machines being developed by public research institutions could be significantly improved.

Figure I - Three types of threshing drums used in threshers: (A) beater type; (B) conventional type; (C) axial flow type

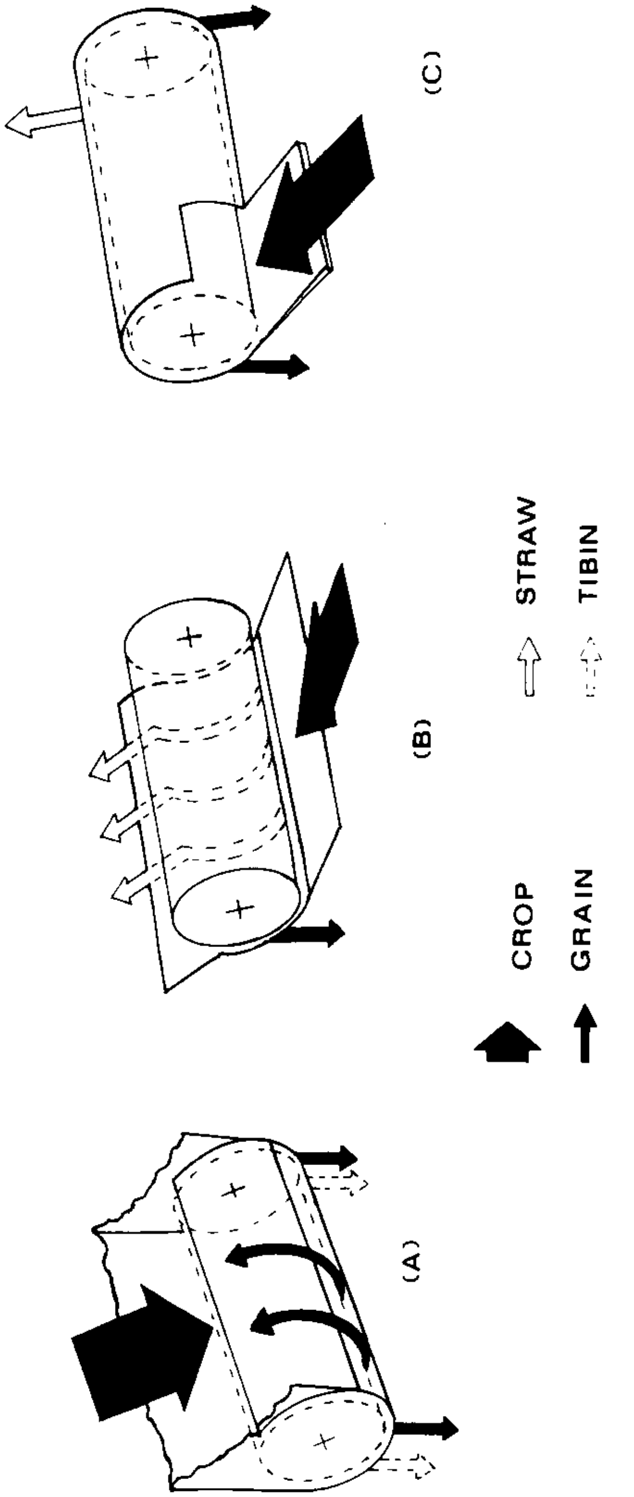


Figure 2 - Beater type "Balaadi" threshers popular in Egypt during the early phase of mechanisation

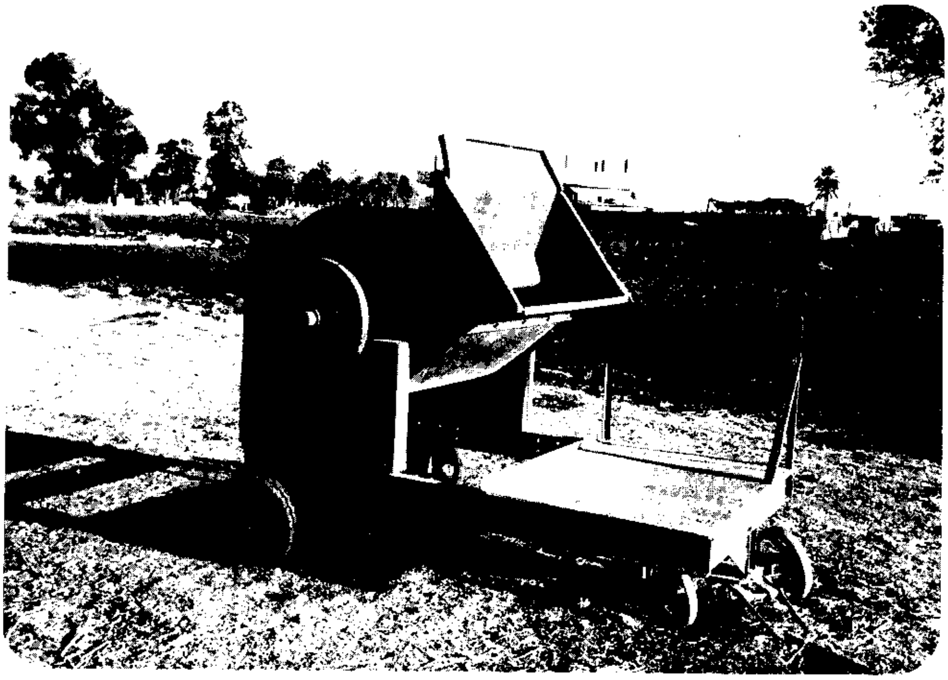


Figure 3 - Schematic drawing of a beater type Turkish thresher popularly used for threshing wheat in Egypt

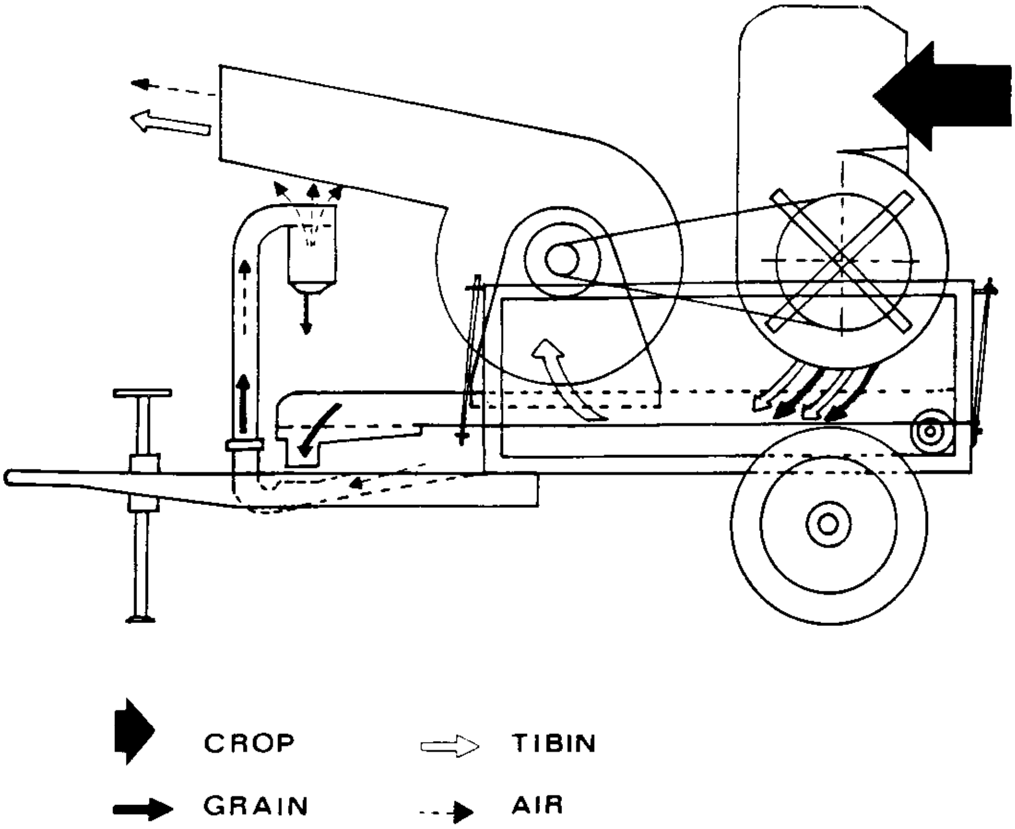


Figure 4 - Dual mode conversion of a beater type thresher: (A) original beater type; (B) dual mode machine shows in an axial flow mode

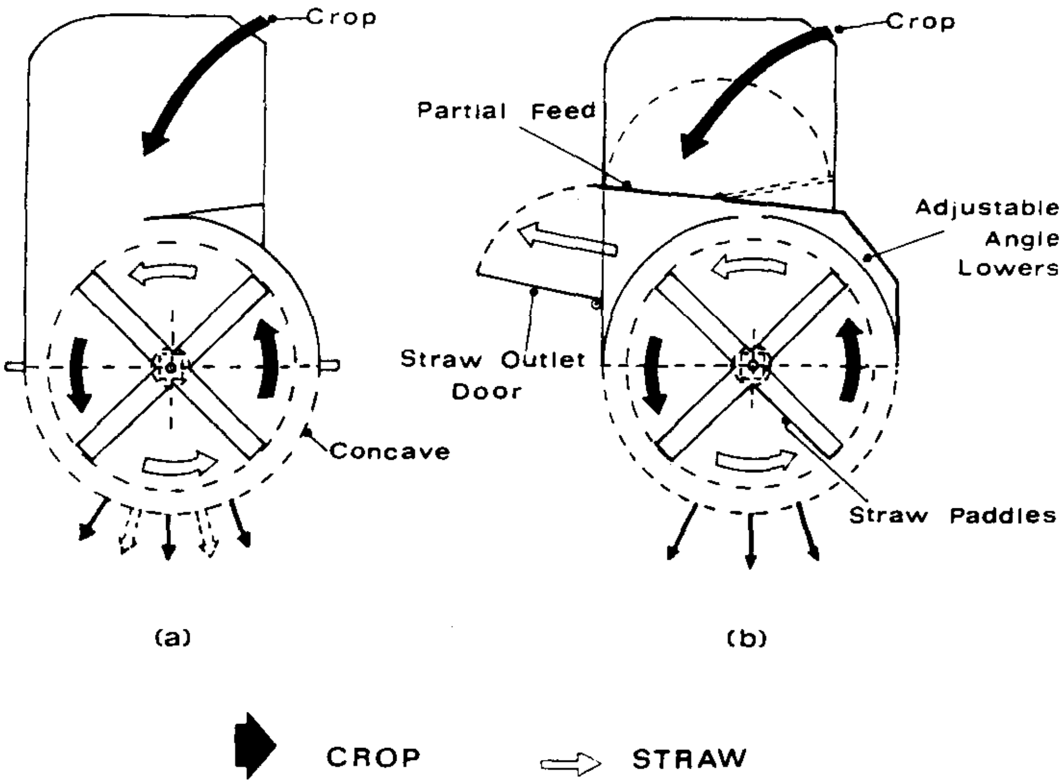


Figure 5 - Adjustable angle drum cover louvers shown in an axial flow mode

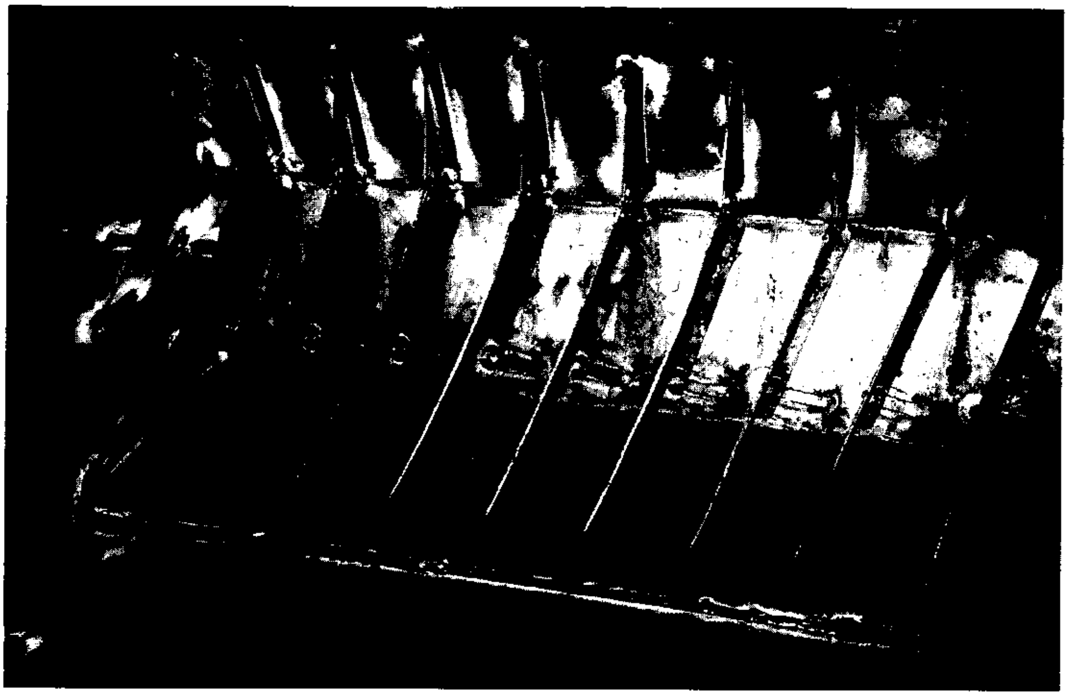


Figure 6 - The dual mode Turkish thresher being used for threshing paddy

A. R1JK

Thank you, Dr. Khan, for your excellent presentation. It is indeed very interesting and I think you have really raised very important issues here. Any questions from the Participants?

A.LARA

We really heard a very nice presentation from Dr. Khan. I have two simple questions. I wonder whether you can say a few words about the need for small manufacturers to have some support in sales. Normally, small manufacturers do not have the function of selling; if they dedicate themselves to selling then they leave the people alone. The second part is if you can say some words about how to scale production, to have the advantage of obtaining better prices for a bigger amount of materials. If we are selling few machines then we have very high prices on raw materials.

A.U. KHAN

I think the two questions are very related. The first one is improving sales of small manufacturers. I think it is a very important issue. My experience, which I have seen in quite a few Asian countries where manufacturing on a small scale has developed well, is that most of them have started a trend of selling from the door: farmers will walk to them. So they are really regional little manufacturers selling in their region. But in that process, what happens? That the farmer would bargain and get him down to the bottom level. There wasn't any margin left for marketing. The price was established at such a low level that for bigger trading houses and other companies to enter into the market was very difficult. We have seen this happening in India, we have seen this in the Philippines, to some extent in Egypt. And when the price was cut down the quality of production was also drop-ping because of the fact that farmers couldn't afford to put in high quality products. So we have a serious problem of how to improve the quality, how to improve the sales coming out of these small manufacturers, and I think they do need help. Now, what kind of help or form of help, is very difficult to say because I know India is faced with this problem very seriously: the quality of local manufacturers from the small scale sector is extremely poor. But then on the other hand the encouraging sign is that a number of tractor manufacturers have started producing their own implements, especially in India and Pakistan some are going into that direction. They are following good standards, but the prices are much higher, so they are starting to cater to a higher level of income and have a different kind of customers. They produce on a one factory and then distribute around with all the normal margins that you have here. I think this dual system will continue till the market is educated, I don't have a quick solution on this problem but I think our efforts, and the government's, at this moment, education and other things to small farmers - we are running a series of seminars in the center of lo-cal manufacturing, to the mechanics, to come in and see what kind of welding is used, what improvements they can do in welding, what improvement they can do in what other material is used, why do you use a spring washer on a farm machinery, little things (split pins and all that). It is some very basic teaching we are trying to give in the hope that this will be one way to improve the product and once the product is improved the price also eventually falls in line. It is a tough one. There is a study looking into how you improve the quality of the equipment, that already is produced at rock-bottom prices now.

The scale of production is related. How do you sell more? Then you can get a scale of production. You can't force the scale of production. So quality is important, and you must tailor to the market. Both of these questions have no easy solution. They will take time, and I think there will always be a dual kind of structure. Some farmers will be willing to pay the higher prices for a while, and they may develop in the long run. I don't think I have answered your question, but it is really a very difficult one.

D.H. SUTTON

Could I ask Dr. Kahn perhaps to comment on another aspect? 1 fully endorse the points he makes, particularly about the importance of working with manufacturers and farmers. Often as engineers most of us, or many of us trained in the mechanical aspects of engineering, we tend to forget that the user is a farmer who doesn't have "mechanical instincts" and therefore needs to be involved in the process (certainly with the small scale machinery). But there is a danger also that I have perceived in a number of Government-funded development institutes: that we get preoccupied with mechanizing a particular operation and regard that operation in isolation and unfortunately that tends to create problems elsewhere in the system. Therefore I would urge engineers always to look at the problems in the context of the whole system, in order not to create further problems. Does Dr. Kahn's experience support that?

A.U. KHAN

I agree with you. I think this does happen, that sometimes they all focus on one thing, disrupting the whole thing. But on the other hand the development oftentimes is done on one single operation, it is work-related. If you talk to people, manufacturers and farmers and all, then you start to look at the whole system. I think it is also a problem of lack of contact between the researchers and the users. If that improves, automatically this system approach comes into prominence.

RO. HEGG

I endorse also the cooperation/interaction with the manufacturers, but I guess that, if there were problems in selecting which manufacturers to work for, I could foresee the time would come, if they are going to have an extra advantage by working with an institute or engineers from an institute, that they may be standing in line to be getting advice and support from you.

A.U. KHAN

I have in the first paper the criteria for selecting cooperating manufacturers. This has been discussed to some extent. I think it is a very important point: you select your own manufacturer and you find out two years later that you have spent a lot of effort in getting to the wrong person.

Generally speaking you'd like to select a manufacturer who is medium-skilled, not very large, not very small. If you have a large guy he probably has a lot of other products going, he is not willing to pay the attention that is required by a new introduction, and that requires staying with a machine for one year or two years and lots of problems. Oftentimes I find that a manufacturer who is a little more creative himself is also very useful because he sees a small problem in the field and he solves it - he doesn't come running to you for all the problems. So you have to have a number of little things to keep in mind. For example I have said "willingness to accept new ideas and suggestions from others". Many manufacturers are so close-minded they are not listening to what you tell them. On the other hand I think every manufacturer makes up his mind depending on his own conditions, but you have to go through this. You should see his other products: are they good quality? If they are junk, then don't go with him, because you very well know that some day he will fail - if he continues to produce junk it won't be long. So don't get associated with somebody who is producing a poor quality machine. I think that is very easy to observe when you go into a factory. He should be willing to provide after sales service if he is providing it for his existing products; he must consider farm machinery production as a primary activity, not a sideline, because again sideline people don't have the knowledge, the understanding of the market and are not willing to put in the effort needed; he must have a desire to establish a sale directly to farmers because then you can improve the machine very rap-idly with him; he should have sufficient resources to stay with the machine for a year or two till it's introduced. Many times you go to a man with a one-man operation or two-men operation and you find that after two months of efforts he gets so tired that he abandons the project and you lost your effort too. So you have to pick out somebody in-between, who thinks he is hungry enough yet he is willing and he still has some re-sources that he will go along. Don't ever work with a government nationalized concern. I say it very strongly because I have worked with many, with totally disastrous results, partly because they don't have any concept of marketing, in fact many of those concerns don't even have a marketing department. They will not help you in any way. You produce and then you end up doing the testing for them, you end up doing the marketing for them. Well, that kind of thing is not what we are wanting. Roughly, that gives you some idea...

D.H. SUTTON

Can I follow that point? One of the ways that governments can assist the development of agricultural mechanization is by part supporting the link between the manufacturer and the development institute. My own Institute, Silsoe Research Institute, had involvement in a scheme called The Agricultural Machinery Partnership, in which Government put in a contribution, the manufacturers put in a contribution, and they were able to draw on the skills and the facilities and services of the Research and Development Center for projects of their choice (in which they wanted confidentiality, etc.). In other words they had access to design engineers and test facilities they would otherwise not have been able to afford. Although the scheme doesn't currently exist it was in its time a very useful scheme and I think a sort of scheme that may well be applied in more developing countries than it is.

A.U. KHAN

I very strongly support that. I think we have tried to improve institutions per se, but they haven't become productive. But if we improve this link in some way, then automatically improvement will occur in the institution itself. I do think there is a tremendous scope for schemes that will encourage the linkages, that some design work is done at the Institute but the prototype is built by the manufacturers, with joint developments etcetera. Oftentimes one party will dominate: the problem is that the Institutions tend to dominate this whole activity. When funds come from the government they become the head and they control the whole. I think this has to be broken down some day. It has to be a joint partnership with the manufacturers. What we are doing is that now we are giving away the money directly to the manufacturer: in these three projects the money is going directly to the manufacturer and it is up to him to work with the Institute. The Institute has no for-mal understanding, but the machines they are picking are the machines we are designing. So I think this is a new experiment and 1 am optimistic that this might bring both of them together.

A. RIJK

So you provide the funds directly to the manufacturer, and you haven't seen any cases in which he takes the money and runs?

A.U. KHAN

No. But we have seen other cases which haven't worked.

A. RIJK

Well, it's true: the person who has the money often controls the other person, and particularly so with government institutions, if they provide the money they will also want to dictate to them.

I had another question. I think also Dr. Lara mentioned it earlier, if I understood well: is there a need for financial assistance to the manufacturers, in particular the agricultural machinery manufacturer (as it is a very seasonal type of a job, so he has to produce but he sells only later)?

In the past - in my previous career with the Asian Development Bank - we tried a few schemes, in particular one in Pakistan, where the agricultural credit institutions would provide loans not only to farmers to buy machines but also loans to the industry, to the manufacturers of small machines. Do you really see a need for that? Maybe from your experience with IRRI under industrial extension programs and so on - how has this been done with the axial flow thresher? Was credit available for the manufacturers or were they established manufacturers who had the resources? Or do you see a need for recommending here in this Forum that financing institutions should provide credit to the small manufacturers?

A.U. KHAN

There is a number of issues that are related. First you asked the question whether IRRI's machines were introduced with any degree of financing to manufacturers: no, there was no financing involved, no governmental schemes. The machines were simple and they didn't require too much investment, all they needed was a welding machine, sometimes were produced without lathing (they went out to get the machining done elsewhere). It involved welding and a little simple cutting, very simple operations. At that level you didn't need any, but when you go higher up the ladder you start to require some financing. Currently Egypt is suffering from this problem of financing - the bank has cut off the financing a little bit. I was talking to some manufacturers and they were saying that the "farm of financing" has dried up currently and so they are all in a bad slump. If you talk of credit, the first need is to the farmer to afford to buy these more elaborate machines. Many manufacturers have access to the commercial banks and to the industrial banks but oftentimes the interest rates are so high that to carry a seasonal product over six months or sometimes a whole year is a very big problem. So I think in that way many manufacturers would not want to borrow, because of the fact that it is such a long period. So most often they will produce for the season and they will try to sell everything they have, which means that either they undersell, because there is more demand in that season, or they are not able to meet all the needs. It is a very difficult question to answer. Some source of money which permits them to build up an inventory on seasonal machines would be helpful, but many of the manufacturing that I have been working with raise their own financing. In fact, IMAGRO, one of the largest companies, to whom I asked whether they had borrowed any money, answered "Not one penny". The money is all their own. But ho , many are in this position? This is a very prestigious company, the largest private manufacturer in Egypt, now producing threshers, backhoes and rotary tillers and the whole range. They don't borrow any money So, it is a mixed bag.

Dr. Jürgen HELLEBRAND
Germany

I feel that the linkage between local research and local manufacturers is really a good pre-condition for the transfer of technology, as was indicated here. The question raised by you, i.e. should be there a program for supporting the local manufacturers?, I would say Yes, because I learned that we have a lot of research institutions in developing countries financed by international money, there is a capacity, but in general there are not enough local manufacturers to take up these ideas to realize this in that country. Therefore I think it is worthwhile to support a development program for small manufacturers in developing countries, especially under the aspect to transfer technology, because I saw in the discussion here this combination of research and small manufacturers is a good way to intro-duce adopted technologies to the local conditions. To strengthen that development you need, I think, the strengthening of the local manufacturers because this is always difficult as they are oriented in general to lines which bring in money in an easier way and this will not come from agriculture in general because you have the problem of marked prices and so on. So, to support manufacturers in these regions by financing and other means I think will lead to improvement in the way of transfer of technology to the developing countries. This was a statement, not a question.

A.U. KHAN

I have seen that, generally, schemes or programs that were helping small manufacturers in the government tended to be straining and a few little things like that. I am not against - I think I agree with you that there is a need for assisting the small manufacturer, but how? The question is: how? One of the issues we have taken is that we are assisting manufacturers but tied to introducing a specific technology. So there is a lot of strings tied to it, in some way. I think we have to carefully think what can help the manufacturer. Now, marketing is an area which, I agree fully, is a weak area. I think there is a need for helping the manufacturer in same way.

A. RIJK

Financing is not the only thing. What has your experience been in the past with the industrial extension program of IRRI? They had quite an elaborate program in the Philippines and in Thailand. Was that successful?

A.U. KHAN

Yes, I think it was fairly successful, not only in Thailand, Indonesia, and all the South-East Asian countries, but no money ever changed hands: it was a strictly technical issue, we designed the machines and said "You produce these machines". Once in a while we'd order some machines, it is true. But only one, two, five maximum. We ordered them to encourage the manufacturer. But we never provided any financing to them. At one stage we had an industrial extension program in which in three countries we had our own staff but we didn't have enough money to send our own staff to various countries, so I thought it would have been nice to link up with the universities and ask them if they could do some industrial extension work with us. It wasn't very successful. Then I tried some manufacturers, and I know one manufacturer (in India) promised all kinds of things; eventually, the money went (it was a small amount, 10,000 US$ for two years or something) and he ended up producing something which he wanted to produce, completely different. I think the issue is how do you guide them to do what you want. But on the other hand it taught me a lesson: that the manufacturer is very resolute in his mind, he is going to do what comes to him, no matter what you tell him to do. But it is better to finance what he wants to do. If he wants to produce a certain machine and you think there is a market and your minds meet together, well, help him in that sense, but don't try to force him by saying: "Here is the money and you do that for us", because he will find some fifty ways of doing something else.

Y. KISHIDA

One thing I would like to comment. From my long observation of his activities, the first time he went to [RRI, in 1967, at that time I could find only some ten manufacturers, but after his activity now we can find more than 100 agromachinery manufacturers. This is almost a 90% effort and the key point has come from his activity. I had a chance to visit Pakistan, where he did the same and now he is doing it in Egypt. I think you have such a great ability and great know-how. But who will succeed you in your activity? And how can we educate such people, to create such ability? This is my question.

A.U. KHAN

I think it is an interesting question. My background is that I grew up in a workshop. My dad used to own an automobile business and he forced us to work on lathes, milling machines, everything, right from our childhood actually. Then, when I came back from the US, I decided I was going to run a business of my own. I started machinery manufacturing in Dehli in the 1950's, way ahead of time. If I had been a little smarter I would never have got into that experiment but nevertheless I started off, and for five years I couldn't make a go of it. But it taught me a lot of lessons on what the small manufacturer is needing, so I am trying to put those ideas back in.

I think the concepts are reasonably dear, from what we have done in IRRI and what we are duplicating. But my biggest problem, that right now I see, is how do you translate this to national scenes, in the government bureaucratic systems? You see, IRRI had a very good system: you had the money and nobody bothered you, you issued instructions and you got that done. We were simultaneously working on fifteen new concepts in a small department with only about, in total, forty people in the department. When you take the same and transfer it to Pakistan, big problems arise, because the national system has all kinds of bottlenecks. Today we are facing - and it was by accident that I went more to the manufacturer, because our workshop doesn't have any equipment, we have the process of buying the material, which is so crazy and you can't hire good workmen because the government salaries are so low - so we have a big problem and this is why l see that the only way you could improve is by letting the manufacturers make some contribution to the research and development effort by producing the prototype (which really involves more money). The paper design and all is not such an expense, which the governmental institutions could do. Transferring therefore is not that easy, I agree, but on the other hand - I had at one time thought of writing a book on these issues (but I got sidetracked in life), but I think they need to be discussed, the whole lot of these issues, which research institutions must learn how to go around them.

I am not the only one who has had this fortunate experience. There are some other people and in India there are one or two good examples where technology developed at an institution was able to widely change the manufacturing scene. But there are more failures, many more failures, and this is unfortunate. But I don't see them improving as rapidly as they could. I think it is the government systems: somehow we have to pull them out of that government system though I don't know how. One way could be to bring the manufacturers into it or finance the manufacturers to develop the machines or to adapt technology in some way.

K.TH. RENIUS

Could it not perhaps be helpful for Egypt if you form an association of manufacturers? In highly-developed countries they have it and so there is much more money to solve the problems via such an association.

A.U. KHAN

This was one of the developments that recently occurred. Dr. El Hossary and myself and many others forced the manufacturers to form an association. I think I should touch this point. Egypt has a very crazy law: they have a military factory (the military is more powerful than the civilian government, there which produces the tractors and the Diesel engines. At one stage they said they were going to produce for the government and the) were going to produce all agricultural implements because they had surplus capacity. So they banned every direct import and every-thing had to go through the military factory: the military factory had to approve your import and charged 8%.

It was really nothing but a money-making operation, and it continued for five or six years. We made noise, we talked to every-body but nobody was listening. The same thing applied to the Diesel engines: they only came through that; a very simple engine was very popular in Egypt for some years (the original German single-cylinder engine), then the military factory started making air-cooled Diesel engines and had the whole thing banned and the government went to the extent of trying to harass some of these people, simple, little mechanics, who were trying to assemble the old engine from parts brought in from India.

But that industry, because the gap in the price is so wide, the small engine is still continuing to be produced from parts imported and some parts locally made and I am quite sure that in the short run we will see very soon manufacturing of that engine going on. So, the moment they formed the Association the Government started listening, because now it was a bigger group. There were articles published on papers and the association was really successful in breaking that lock-jam just recently, so now they have opened imports to anybody and I have a feeling this will change.

I agree with you. For some time at the earliest stages of development there are usually not enough manufacturers who have the resources and time to get together, and often when they look at each other they are competing, too. It takes a certain degree of maturity before you can bring an association into being but it is a useful exercise.

A. RIJK

Any other question? If not, I think that we can close this second Session. We have had two very interesting presentations, one in the private sector by Dr. Kahn who has been doing this for many years in Asia and now in Egypt, and another case, the case of a government operated enterprise.

First of all I would like to thank the key-note Speakers and also all the Participants for their valuable contribution.