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HIGH LEVEL CONSULTANCIES AND TRAINING

DP/SYR/86/009

SYRIA

Technical report: Solar systems*

Prepared for the Government of Syria
by the United Nations Industrial Development Organization,
acting as the executing agency for the United Nations Development Programme

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Based on the work of S. V. Szokolay, solar systems expert

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Vienna

* The views expressed in this paper are those of the author and do not necessarily reflect the views of the Secretariat of the United Nations Industrial Development Organization (UNIDO). Mention of company names and commercial products does not imply the endorsement of UNIDO. This document has not been edited.

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CONTENTS

APPENDICES

FIGURES

1. INTRODUCTION

The writer was commissioned by UNIDO to go to Syria as a 'sola. system equipment expert' for the first part of a split mission, for one month between June 15 and July 16, 1989. The second half of the mission (for three months) is scheduled for June - September, 1990. The mission is part of a broader project of high-level consultancies and training, including a whole range of industries, from tanneries to pharmaceuticals, from cement works to sugar and alcohol production.

1.1 Purpose

To assist the Government in strengthening existing solar energy system facilities and advise on the establishment of new production capacities/lines and the introduction of related technologies.

1.2 Duties

"Fact-finding / trouble shooting / identification of key problems with regard to existing facilities in terms of production technology, productivity, quality control, repair and maintenance procedures, etc.

Technical examination and assessment of existing solar systems with the view of improving the performance characteristics of existing design and production facilities and expanding technological capabilities and market of products most needed.

Preparation of work programme for the implementation of solar energy equipment programme to be developed for the introduction of modified and/or new design and production technologies including infrastructural requirements, hardware, manpower, training, timing needs and financial consequences.

Elaboration of a Technical Report on each split mission describing the course and results of the respective field assignments including findings, conclusions and recommendations for follow-up activities."

2. MAJOR RECOMMENDATIONS

(1) The Solar Factory should be moved to the parent company's site at ADRA, where one bay of approximately 100 m x 25 m of the existing factory could be made available without any difficulty.

(2) The Factory should establish a design and development section (say, with two young engineers), which should actively promote major industrial process heating installations, in consultation with the Renewable Energy Council of the Prime Minister's Department.

(3) A pressed steel sheet absorber (of the Eltron type) should be manufactured locally: pressing by the Barada Company and welding by the Solar Factory (Metalco). In order to speed up the welding process, a machine with 21 spot- (resistance-) welding heads and a ring-head should be obtained and installed.

(4) The aluminium collector frame section should be redesigned, along the lines proposed (section 8.2 and Fig.8), to accelerate production and improve quality.

(5) A polyurethane injection machine should be obtained and used to provide the back insulation of the collectors.

(6) An installation and maintenance section should be established, to avoid incompetent installations and the lack of maintenance, which tend to undermine the credibility of solar systems. Maintenance contracts should be offered with all installations.

(7) Two training courses should be mounted, one for technicians and one for professionals, of about two weeks duration, full time. The latter should include the introduction of some computer programs used for design, which would necessitate the acquisition of a microcomputer (approximate cost: $ 2800). The computer would be used throughout the second part of the split mission (3 months) to further train the selected design engineers.

(8) The performance of completed installations should be monitored, in order to find any mistakes and promote improvement. An analogue-to-digital converter card and appropriate software should make the above microcomputer also suitable for data logging.

3. CHRONOLOGY OF ACTIVITIES

June	15	leave Brisbane (Australia)
	18	arrive Vienna
	19	briefing
	20	leave Vienna, arrive Damascus
	21	UNIDO; intro. to Factory
	22	UNIDO: passport/visa, admin., lost luggage
	23	- FRIDAY
	24	tour of Factory, briefing by A.Khorzom
	25	interview Factory manager J.Ezzaldin visit SSRC
	26	visit Al Nahil hotel installation GOEI office, computer room
	27	visit SASMO, police barracks and several apartment block installations
	28	visit solar village (near airport)
	29	conference with I.Khankan and others
	30	- FRIDAY
July	1	design hypothetical system: cost/benefit study
	2	visit to ADRA, the Metalco factory
	3	computer work at UNIDO at Factory: materials lists and prices visit LAVA workshop
	4	computer work at UNIDO visit ITRC, visit ORE (Dr.M.Kordab)
	5	seminar at SSRC, computer demonstrations
	6	visit to Oriental Underwear Co. factory
	7	- FRIDAY
	8	design work at factory; GOEI office: confer with I.Khankan and Abdul-Hafiz Dalati
	9	computer work at UNIDO at Factory: air heater and drying projects meeting at ORE
	10	GOEI office: meeting with I.Khankan and Dr.Kordab meeting with Diector-General, M.Munajed meeting at ORE, re. solar school
	11	GOEI: I.Khankan UNIDO: admin and Dr.Bachaan
	12	leave Damascus, arrive Vienna
	13	debriefing
	14	leave Vienna
	16	arrive Brisbane.

4. CURRENCY AND SOME RELEVANT COST ITEMS

The official exchange rate of the Syrian pound (SP)
at the time of the mission (July, 1989) is US $1 = SP 11.20
the incentive (tourist) rate is US $1 = SP 20.00
It is understood that the unofficial rate is between SP 40 and 50 for 1 US $ and that many financial calculations by official bodies are based on the conversion rate of US $1 = SP 40.00

Petrol (gasoline):	SP 15/litre, or in hard currency: US $ 155/tonne = $ 0.155/kg = $ 0.13/L
Light (eg.diesel) oil:	(same as kerosene) a 20 L can costs SP 55, which gives SP 2.75/litre This is a heavily subsidised price to assist industry, goods an public transport, and this is why the import of diesel-engined cars is not permitted.
Heavy oil :	SP 815/tonne = SP 0.815/kg = SP 0.70/L or in hard currency: US $ 82/tonne = US $ 0.082/kg
Butane gas :	SP 40 for a 12 kg bottle, ie. SP 3.30/kg
Electricity :	An average household's 2-monthly account includes SP 10 for the meter rental and some SP 55 for tax and stamp duty, over and above the consumption charges. The rates are: SP 0.305/kWh for the first 100 kWh/2-mths, SP 0.55/kWh for consumption over the above limit. If the fixed charges are included, it is reasonable to take a flat rate of SP 0.55/kWh. If heavy oil is used for generation, assuming a calorific value of 11 kWh/kg and a generating efficiency of 0.33: 0.082 / (11 x 0.33) = US $ 0.023/kWh This may be doubled to allow for capital charges, giving US $ 0.046/kWh Multiplied by the 'official' exchange rate this gives practically the same as the above rate: SP 0.52/kWh
Water heating:	The daily hot water consumption of an average household is taken as 200 L. To heat this by 40 K (eg. from 20 to 60°C) requires 200 x 1.16 Wh/L.K x 40 K = 9.3 kWh electricity or 9.3 / (11 x 0.65) = 1.3 kg of light oil (where 0.65 is the boiler efficiency)
Aluminium :	SP 155/kg, or in hard currency: US $ 2.50/kg
Steel :	SP 29/kg, or in hard currency: US $ 0.575/kg

5. ORGANISATION

The writer was attached to the General Organisation for Engineering Industries (GOEI), (primary contact officer: Mr. Ismat Khankan) and seconded to the Solar Energy Factory, a division of the Metallic Construction and Mechanical Industries Co. (METALCO). The technical manager of this factory, Mr. Akil Khorzom (engineer) acted as guide and interpreter throughout the mission.

The Industrial Testing and Research Centre (ITRC) is responsible for industrial research, product development, product testing and quality control, and was suggested as a body relevant to the present project. It was, however, stated by Mr. Taufik Sheikh-el-Shabab, the acting director of the Centre, that this organisation has no interest in solar energy or the related industry. (The quality control project of the Centre, funded by UNDP and run by Dr.Farouq Fawzi of Holland, embraces four selected industries. of which solar is not one.)

Solar and wind energy work is coordinated by the Office of Renewable Energy (ORE) and the Renewable Energy Council of the Prime Minister's department, directed and chaired (respectively) by Dr. M.Kordab, a professor of the University of Damascus. ORE expects a $ 500 000 project proposal to be approved by the Department of Technical Cooperation for Development later this year (see Appendix 2). Dr.Kordab is working on the preparation of a major industrial demonstration project.

The Scientific Study and Research Centre (SSRC) is a completely autonomous unit, which belongs to the Department of Defence, but is controlled directly by the President. Its primary purpose is research, but it also has a post-graduate teaching function through its Higher Institute for Applied Sciences and Technology (HAIST), primarily for the training of their own future personnel. The head of the solar energy group is Dr.Abd-el-Hadi Zein.

SASMO, the Syrian Standards organisation issued a series of solar energy-related standards, which are listed in Appendix 3.

6. HISTORICAL BACKGROUND

In 1980, when there were only a few small private workshops producing solar water heating equipment, a techno-economic study was carried out by the GOEI of the Ministry for Industry, which concluded with the recommendation that a public sector factory for such solar heating equipment should be established.

The GOEI gave the task of setting up such a factory to the Metallic Construction and Mechanical Industries Co. (METALCO). The parent company has its factory at ADRA, just outside Damascus, but the Solar Energy Factory was set up in an existing building in the Old Harasta Rd. of Damascus, during 1982. An advisor made available by the British Overseas Development Ministry assisted in this process. Production started in June 1982.

Fig.1 shows the recommended areas and sequence of operations as presented in the above study and Fig.2 shows how this has been translated into reality in the existing building.

Up to 1986 the factory produced a collector based on a galvanised steel tube grid, with a fitted absorber sheet. In that year a large quantity (some 6000) 2 m x 1 m absorber plates were purchased from Stiebel Eltron (a German firm, manufacturing in Greece). These are pressed steel sheets, resistance-welded together, with integral waterways. Some were supplied in stainless steel, with an IMCO selective surface, but most only mild steel, subsequently painted matt black. The casing was modified to fit (Fig.3).

The thermosiphon loop is fed into a jacket, surrounding the tank, which acts as a heat exchanger. The primary circuit is a closed loop, fitted with a nitrogen-filled expansion bottle and filled with a 20% aqueous solution of ethylene glycol. Fig.4 shows the standard domestic size unit, with 4 m² collector and a 220 L tank. The unit is supplied with a steel stand, which also supports a cold water feed cistern. As the unit is only exposed to the pressure due to this elevated cistern, which also allows for expansion, there is no need for any safety valves.

In 1986 a major report on the solar energy industry was commissioned by the SSRC, funded by the EEC and prepared by CISE. This report is briefly discussed in Appendix 4.

In 1988 a conveyor-type assembly line has been designed and its construction started, but then all further investment has been stopped, so the installation is still incomplete. The goods lift (elevator) indicated on the plan (Fig.2) has never been installed, so all vertical movement of materials and products (as well as of tools and other equipment) takes place by hand, via the external stairs.

7. THE PRESENT SITUATION

The full production capacity of the factory is estimated as 5000 DHW units p.a., or its equivalent (ie. 10 000 collector panels). The reduced production target in 1988 was 1500 units and Table 1 shows the raw material and component requirements for this number of units. As there appears to be a lack of hard currency and the stock of raw materials has been depleted, at present there is no production at all.

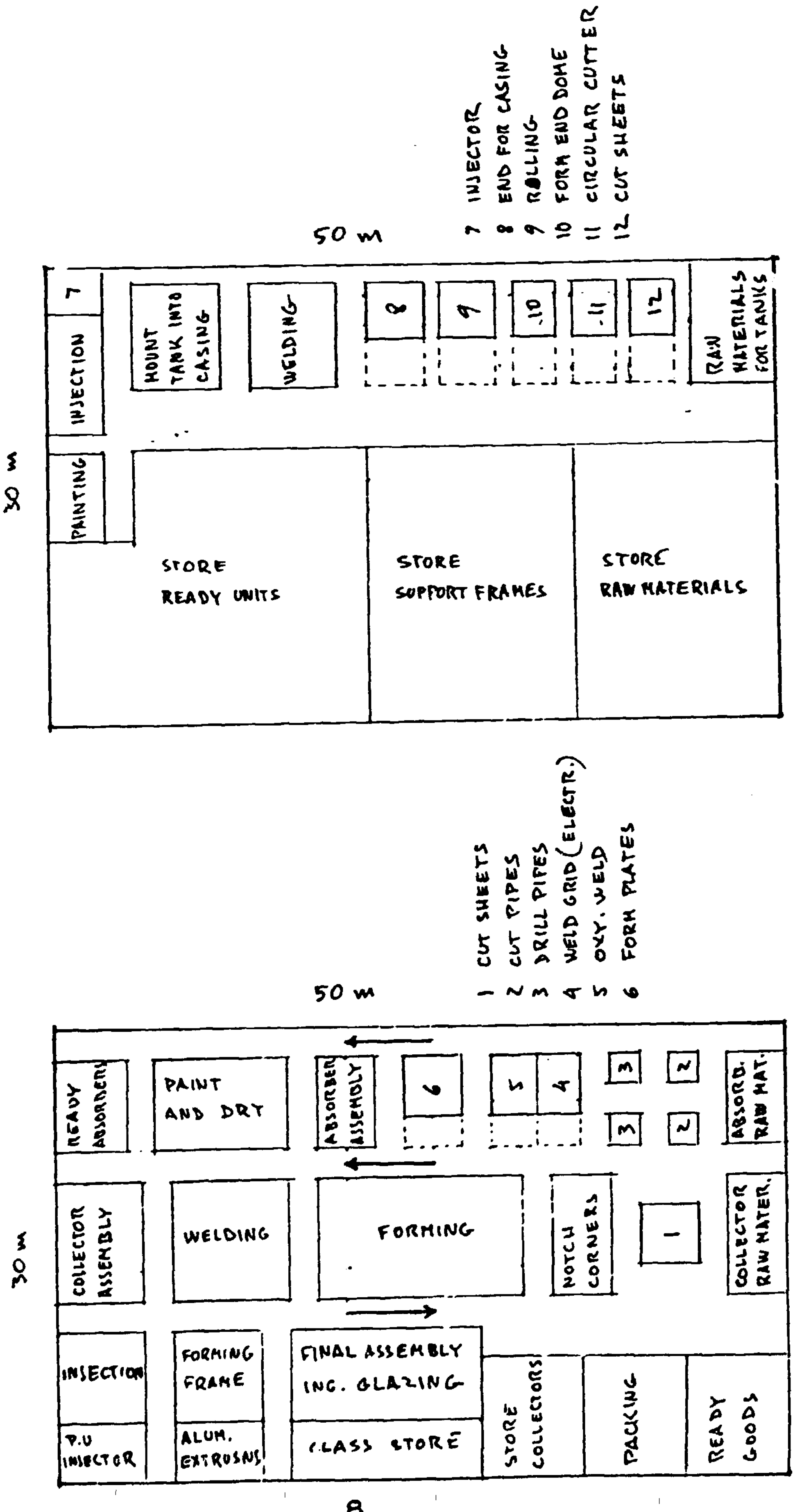
However, the statement of the factory manager (Mr.Ezzaldin), that the lack of materials is their 'only problem' sounds somewhat hollow, as the factory has a considerable stock of ready collectors and tanks and no effort is made to sell these units. It is understood that the main problem is the very high cost of the unit (SP 32 000), which is some 10 months' full salary for a young professional and which very few people are prepared to pay, although many are interested in having such units. This however is not to deny the problem of hard currency.

Any comment on this macro-economic problem would be beyond the scope of the present brief, but the responsible officer of GOEI advised that this problem will disappear by next year and that the present study should be based on the assumption of ample raw material availability.

1980 STUDY:

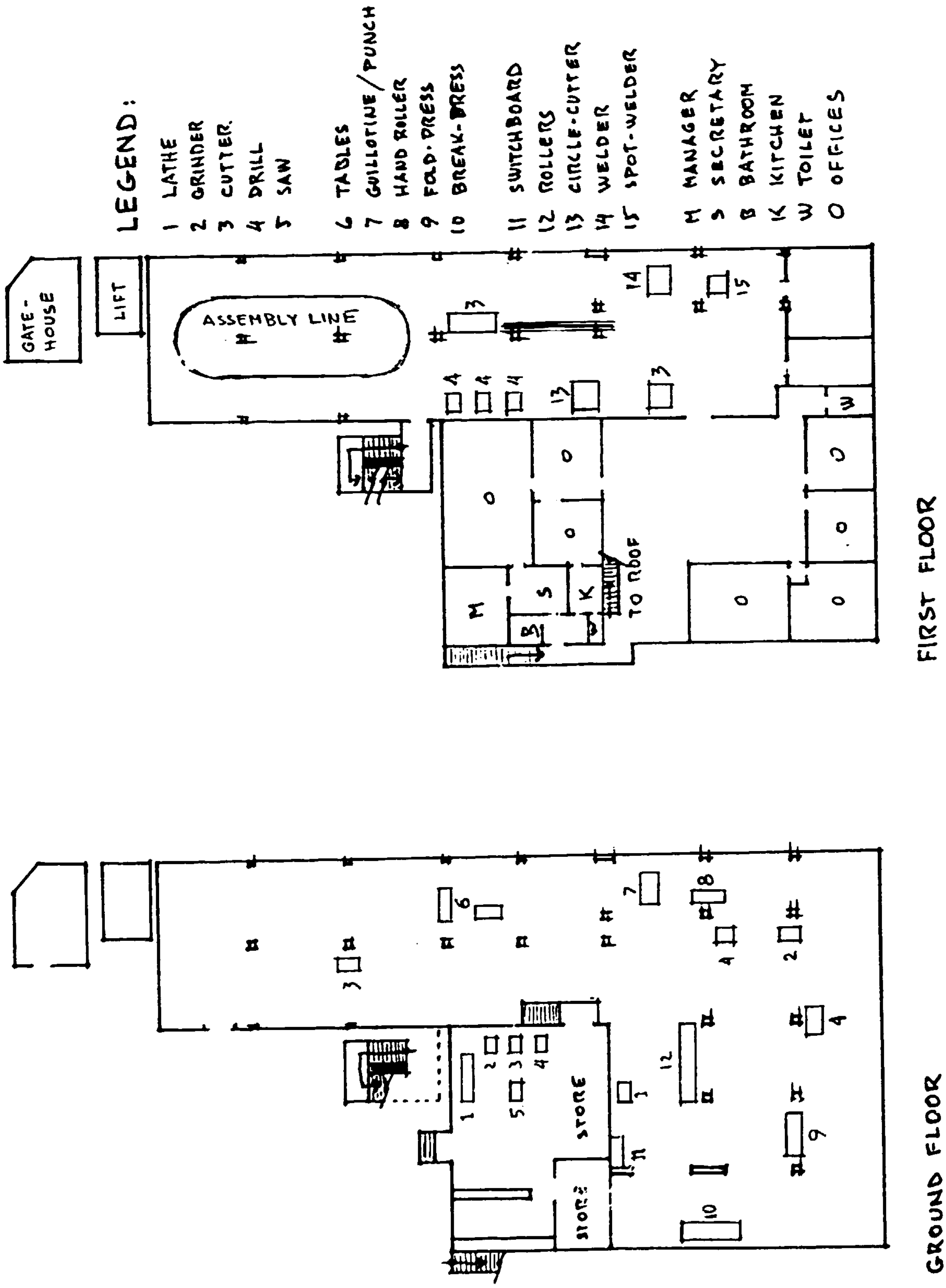
SPACE & FLOW OF OPERATIONS

FIG. 1.



EXISTING FACTORY

FIG. 2.



وزاره الصناعه

معمل الطاقه الشمسيه

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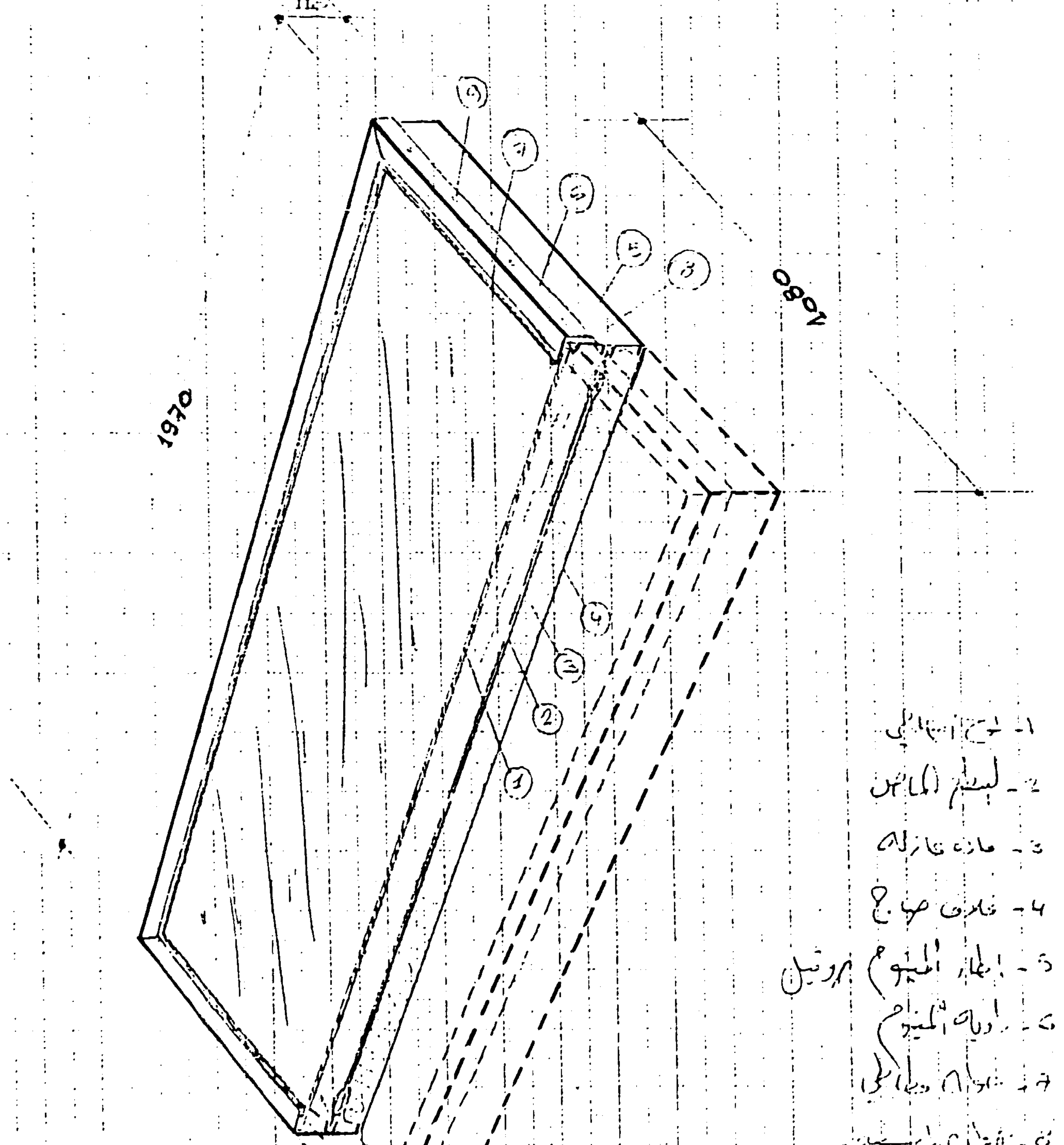
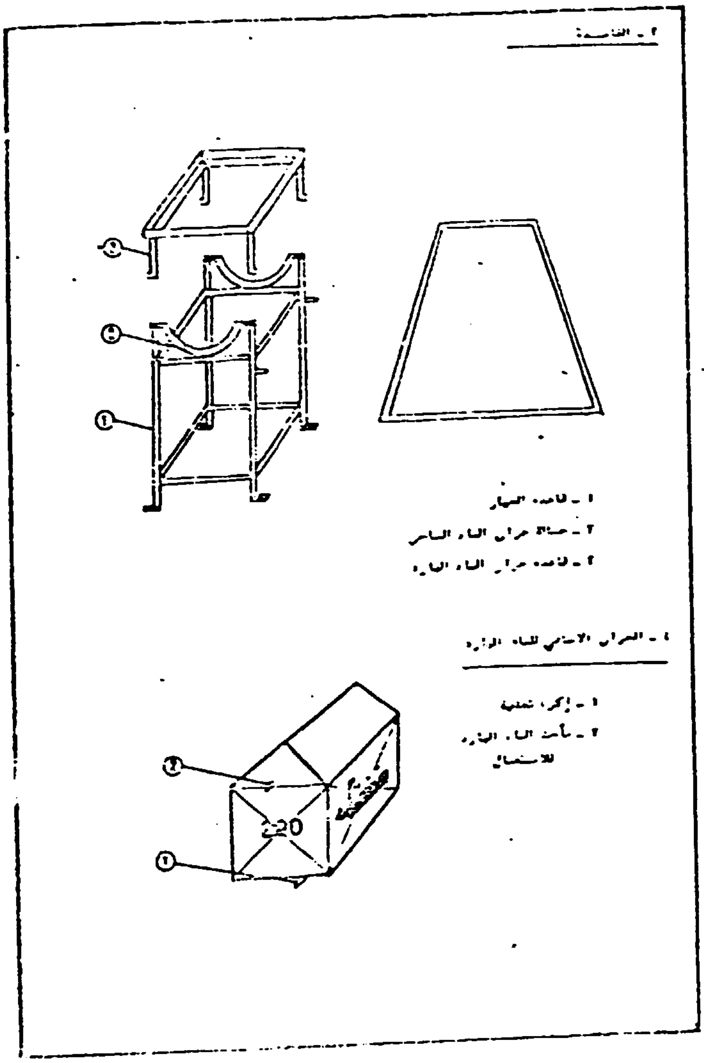
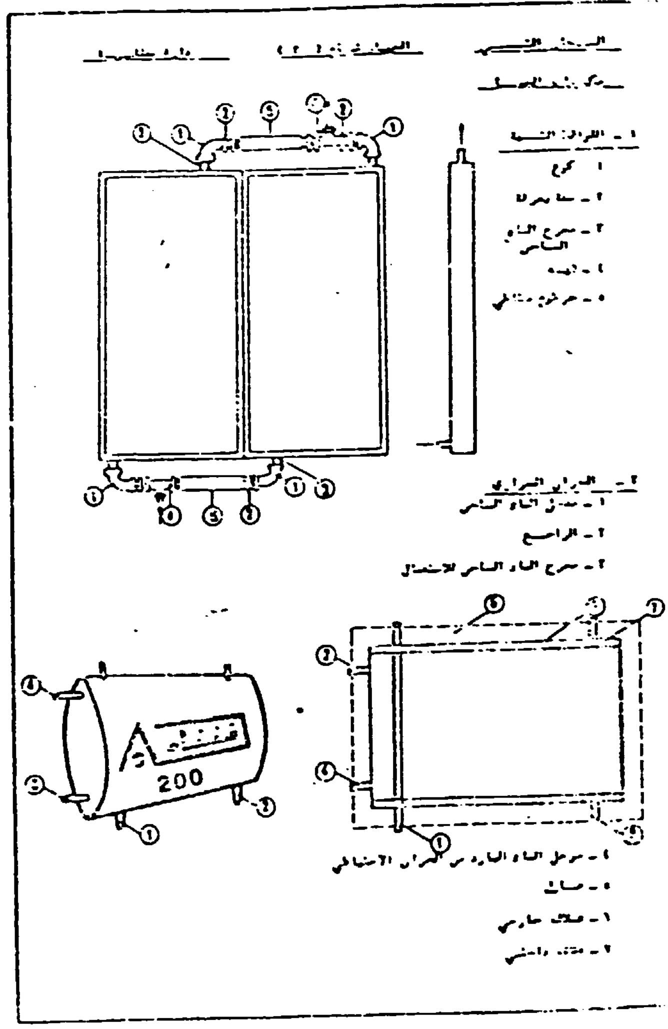
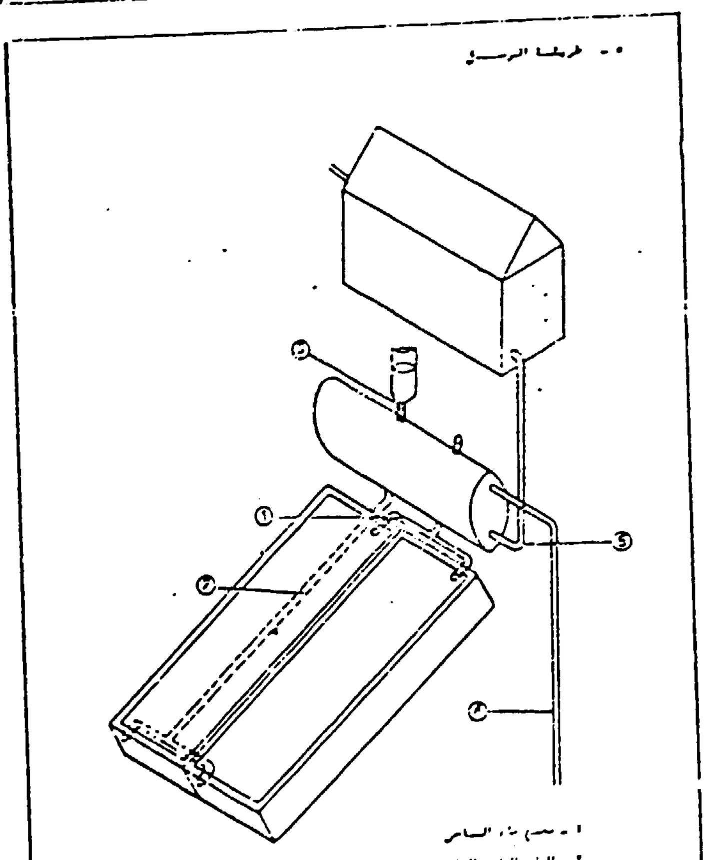


FIG. 3

THE NEW COLLECTOR







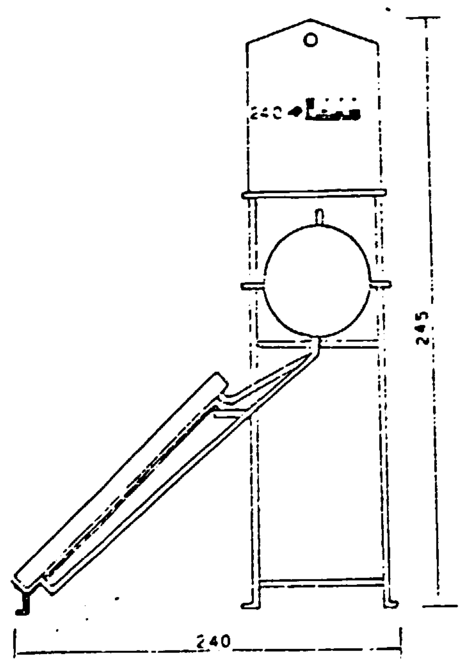


FIG. 4.

THE STANDARD D.H.W. SYSTEM

TABLE 1 Materials and components for 1500 DHW units

Collector	absorber plates*	3000	SP 865	2 595 000
	1 mm steel sheet	72600 kg	28.35	2 058 210
	alum.frame extrusion	7500 kg)		
	alum.angle glazing bead	4890 kg)	155	1 920 450
	6 mm glass	6300 m²	99	623 700
	foam glazing strip	9300 m	0.05	465
	plastic glazing strip	18000 m	35	630 000
	rock wool	9000 kg	10.50	94 500
	plastic U-strip (absorber)	9150 m	35	320 250
	glue (for plastic)	150 kg	12	1 800
	mastic	750 tubes	110	82 500
	pop-rivets	144000	0.40	57 600
	screws	36000	0.25	59 100
	teflon tape	7500 rolls	15	112 500
	connector sleeves	6000	8	48 000
	connector spigots	6000	8.50	51 000
	plastic sealing washers	6000	18	108 000
Tank	2 mm galv.steel sheet	145000 kg	SP 28.95	4 197 750
	1 mm galv.steel sheet	15900 kg	28.35	453 317
	galv.steel pipes	3983 kg	26.35	104 952
	connector sleeves, 32 mm	1500	15	22 500
	25 mm	1500	12	18 000
	20 mm	6000	8	48 000
	13 mm	6000	5.85	35 100
	paint (750+1500+750+750)	3750 kg	28.95	108 563
	expansion vessels	1500	30	45 000
Cold tank	1.25 mm galv.steel sheet	90500 kg	21.55	1 955 663
	16 mm rod (for hinges)	36 m	8	288
Support frame	rolled steel angles	97320 kg	8	778 560
	rolled steel flat bars	5490 kg	8	43 920
	bolts and nuts	9000	0.60	5 400

*The complete collector was priced at SP 7200. This was based on converting the US $ 75 absorber cost to SP 3000. Apparently it was decided early July to use the official rate of SP 11.20/$, which - with some handling cost added - gives the SP 865 price.

Three collectors have been tested for the Factory by the SSRC:

(1) the old model: galvanised steel pipe-grid and fitted sheet,
(2) the current model: Eltron absorber, matt black painted, and
(3) the same, but with a selective (IMCO) surface.
The results are shown in Fig.5.

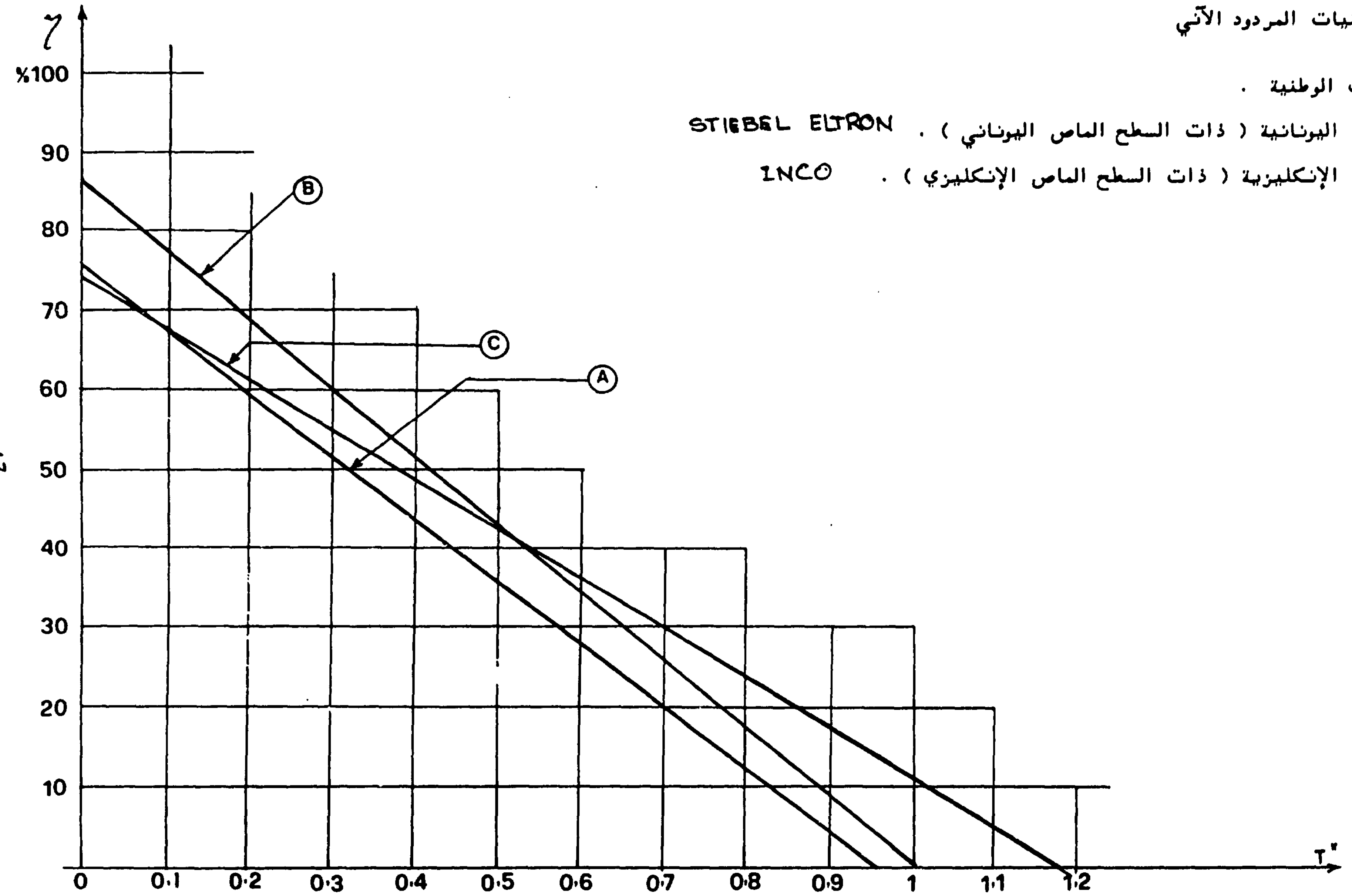
A visit to the parent company's (Metalco's) factory at Adra showed that large factory spaces are half-empty. Without too much effort one bay of approx. 100 m x 25 m could be made available to house the solar system production lines.

منحنيات المردود الآني

A - للمجمعات الوطنية .

B - للمجمعات اليونانية (ذات السطح الماص اليوناني) . STIEBEL ELTRON

C- للمجمعات الإنكليزية (ذات السطح الماص الإنكليزي) . INCO



$$T = \frac{Tm - Ta}{I} \times 10$$

$$tm = \frac{tin + to}{2}$$

FIG. 5

It is the first and most important recommendation of this report that the Solar Energy Factory in Damascus be moved as soon as possible to Adra. The reason is not only that the existing premises are cramped and totally unsuitable for proper functioning of a factory, but also that at Adra some of the machinery of the parent company can be relied on to assist in solar equipment production.

Fig.6 is a tentative proposal for the layout of the four component production lines: (1) absorber, (2) collector, (3) tanks and (4) support frames. This assumes that the proposal for manufacturing the sheet steel absorbers is accepted, that the pressing will be done at the Barada factory and the welding and assembly at the Solar Factory.

8. THE PRODUCT

8.1 The absorber

Two kinds of absorbers have been used:

(1) the Stiebel Eltron pressed steel, welded panel

(2) the old galvanised steel pipe grid and fitted plate.

There are two schools of thought favouring the two, respectively. There is no doubt that the former gives a better performance and that the latter is very labour-intensive*, but it is thought that the hard currency (material-) cost of the latter is less, therefore it would be more favourable. It was therefore decided to make a comparative study:

	ELTRON	PIPE-GRID
size	1.96 x 1.02 m	1.70 x 1.82 m
area	2 m^2	1.4 m^2
mass	25 kg	30 kg
mass / unit area	12.5 kg/m^2	21.5 kg/m^2
unit cost ($575/tonne)	$ 75	$ 17.25
cost / unit area	$ 37.50/m^2	$ 12.30/m^2

The cost of the second type is much less in hard currency terms.

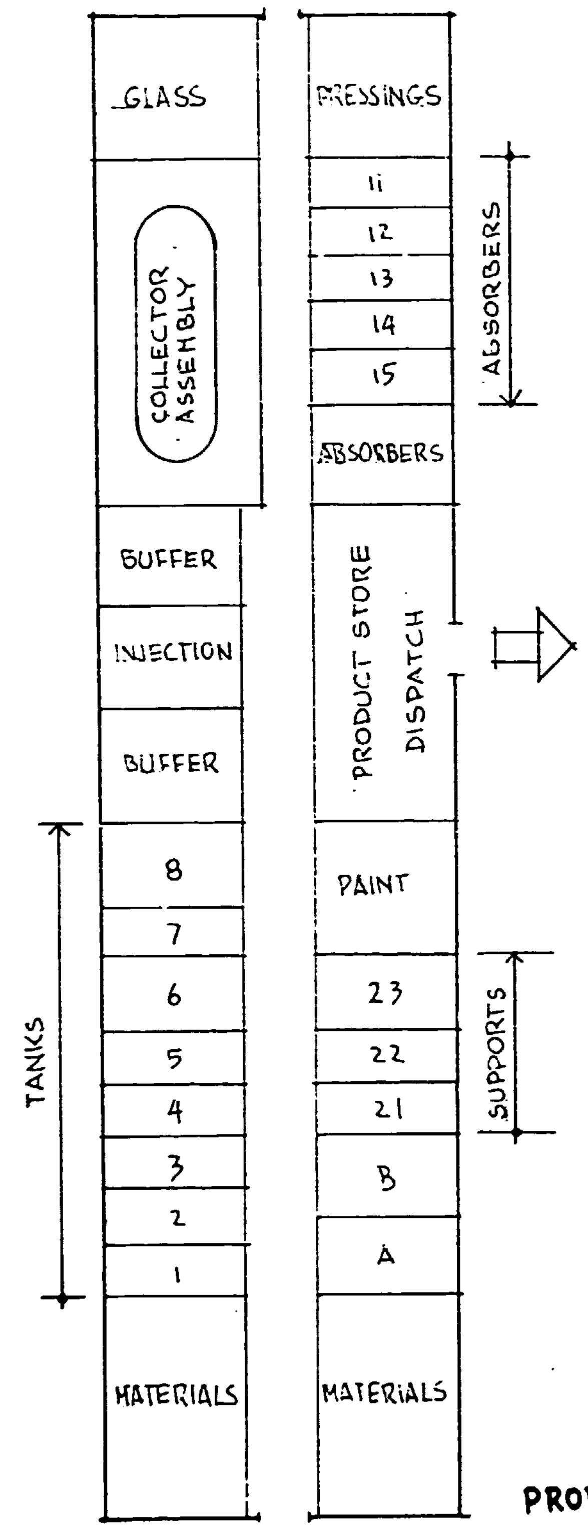
An alternative absorber construction has also been suggested (by Dr.Kordab): a pipe-grid, but using thin-walled 10 mm steel tubes for the risers, which can be produced by the Iron and Steel Manufacturing Co. (of the GOEI) at Hama. An aluminium extrusion of the type shown in Fig.7, could be produced at the Aluminium Co. (of the GOEI) at Lattakia. Cut to the appropriate lengths, these would be pre-heated and pressed onto the steel tubes. Their cooling and consequent shrinking would produce an almost perfect thermal connection. The finned tube would be 160 mm wide, thus the old 8-tube absorber could be replaced by a 6-tube model.

---

*8 riser tubes of 13 mm + 2 headers of 25 mm, cut, drilled and welded + 1 mm sheet, with 8 x half-round pressings, fitted and welded. The thermal contact between the riser tubes and the pre-formed sheet is rather poor, as it is only due to the spot welding and the rather loose fit. Hence the difference between the two collectors' performance characteristics (see Fig.5):

- tube-grid and plate: $\eta = 0.76 - 8 \ T/G$
- pressed sheet: $\eta = 0.86 - 8.6 \ T/G$

(the heat loss coefficient of the latter is slightly larger, but it could be improved quite easily)



ABSORBERS:

11 CLEAN
12 EDGE-WELD
13 SPOT-WELD
14 OUTLETS WELD
15 PAINT

TANKS:
1 CUT SHEETS
2 CIRCULAR CUT
3 FORM END DOME
4 ROLL CYLINDER
5 CASING ENDS
6 WELDING
7 TESTING
8 ASSEMBLY

SUPPORTS:
21 CUT PIPES
22 CUT ANGLES
23 WELD

A. CUT FRAME EXTRUSIONS
B. CUT BACK SHEETS

FIG. 6.

PROPOSED FACTORY LAYOUT

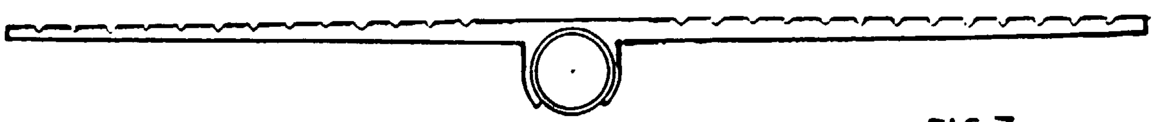


FIG.7.

FINNED TUBE ABSORBER

The view of the present writer is that the aluminium is expensive, that the welded tube-grid is a very laborious production method, that the heated aluminium fins would tend to warp and that the efficiency would probably be lower than that of the pressed steel sheet absorber. In the latter, some 90% of the absorber area is wetted, so the panel does not rely on heat transport by conduction along a thin metal profile. However, without too much capital outlay, the technology could be tried and the product could be tested.

The pressed steel sheet absorber could be manufactured in Syria. The Barada factory can handle 1 m^2 pressing. Taking the 2 m x 1 m sheet, it can be pressed in two steps: first one end, then the other, as the panel is symmetrical. The pressing die already exists. The welding could be done on the existing spot (resistance-) welding machine, but the production would be improved considerably by obtaining and installing a resistance welding machine with 21 welding heads. If the welding head is interchangeable, then a ring-head should be obtained, or else a separate resistance welder with such a head should be installed for the fixing of the screw-threaded inlet and outlet connectors.

The cost of steel for this panel would only be US \$ 14.37, ie. \$ 7.18/m^2 (compared with the above \$ 35.50 or \$ 12.30)

This is the solution strongly recommended by the writer.

8.2 The collector

The current model has an extruded aluminium frame (Fig.8). Comparison of the efficiency curves (Fig.5) shows that the no-loss efficiency of this collector is exceptionally good: 0.86, as against 0.76 of the older model, but the heat loss coefficient is worse: 8.6 W/m^2K, as compared with 8.0 W/m^2K for the older model. It is suspected that the reason is the continuous absorber support fin of the frame member, which - even with the plastic gasket - would provide a thermal bridge to the outside.

The other criticism is that the assembly relies on the hand-drilling of over 100 holes and the use of screws and pop-rivets for fixing
(a) corners of the frame
(b) the back plate to the frame
(c) the angle glazing bead.
Incidentally, the last item is a 30 x 30 mm angle, as this is said to be the only one available, whereas 20 x 20 mm would be adequate. This is not only a waste of material, but it also reduces the effective aperture area by 1 cm all around.

The writer suggests that the frame should be redesigned, in a form similar to that also shown in Fig.9. This would achieve four aims:

(1) Simplified corner fixing: two self-tapping screws, located by the groove, driven into the screwing channel, would give an adequate fixing.

(2) Elimination of thermal bridge: adequate absorber support could be provided by a solid plastic support block at each of the four corners. This could be injection-moulded at the Barada factory. It would be dimensioned so as to give a snug fit into the aluminium frame.
(3) Elimination of screwing for the glazing bead: the frame would have a snap-in glazing bead, fixed by pressing in, without any screws, which could be removed (eg. in case of glass breakage) by inserting a srewdriver from the side.
(4) Elimination of pop-rivets for the backing sheet: this could be inserted into the slot of the frame during assembly and held in position without any rivets.

At present rock-wool is used for the back-insulation, in a nominal 50 mm thickness. The factory of the Military Housing Establishment produces some first class mineral wool batts and blankets, varying between 30 and 120 kg/m^3 density. The material used by the solar Factory however, looks like leftovers, a lumpy, amorphous material, with a density more like 300 kg/m^3. This is difficult to handle and consequently the space left for insulation is often incompletely filled or the insulation is compressed, thus its insulating property reduced.

Two alternatives may be considered for improvement:
(1) Order from the rockwool factory the foil-faced Fibromat sheets, cut to size (approx. 1 m x 2 m). This product will have to be handled carefully, to avoid breakages or compression.
(2) Obtain a polyurethane injection machine and use an in-situ foam for the back insulation. This is a semi-rigid foam, therefore the backing sheet could be reduced in thickness, as the foam provides some stiffening. The conductivity of this may be about 0.025 W/m.K as compared with 0.036 W/m.K for the former (0.042 W/m.K for the higher density product).

The writer strongly recommends the second solution, which would allow the reduction of the insulation thickness to 40 mm. The insulation resistances can be compared as:

40 mm polyurethane,	k = 0.025 W/m.K,	R = 1.60 m^{2}K/W
50 mm rock wool,	k = 0.036	R = 1.39
	k = 0.042	R = 1.19

which shows that the 40 mm PU foam will be better than the 50 mm rock wool.

With the pressed steel absorber, the new frame and the polyurethane insulation a first class collector could be produced.

9. COMPUTER RUNS

The writer provided one of his own programs, ACTSYS (for ACTive SYStems), based on the widely used 'f-chart' method, which is part of the ARCHIPAK suite of programs. This can estimate the monthly and annual solar fractions and the net solar energy supplied by a defined system.

The program runs on an IBM XT (or compatible) microcomputer, with 640 K memory, using an 8087 numeric co-processor. Great difficulties were experienced in finding a machine to use. The company has none. The GOEI has an NCR machine, primarily used for payroll work, but no numeric co-processor and only 256 K memory. The SSRC has a suitable computer, the programs were copied over to their hard disk and demonstrated, but they could not allow its use for other purposes. Finally UNIDO permitted us to use one of their machines. This had an adequate memory, but no numeric co-processor. The programs had to be re-compiled for runs without such a co-processor.

It will therefore be one of the recommendations of this report that the design office of the factory be supplied with a suitable computer, as specified in Appendix 9.

10. COSTS vs. BENEFITS

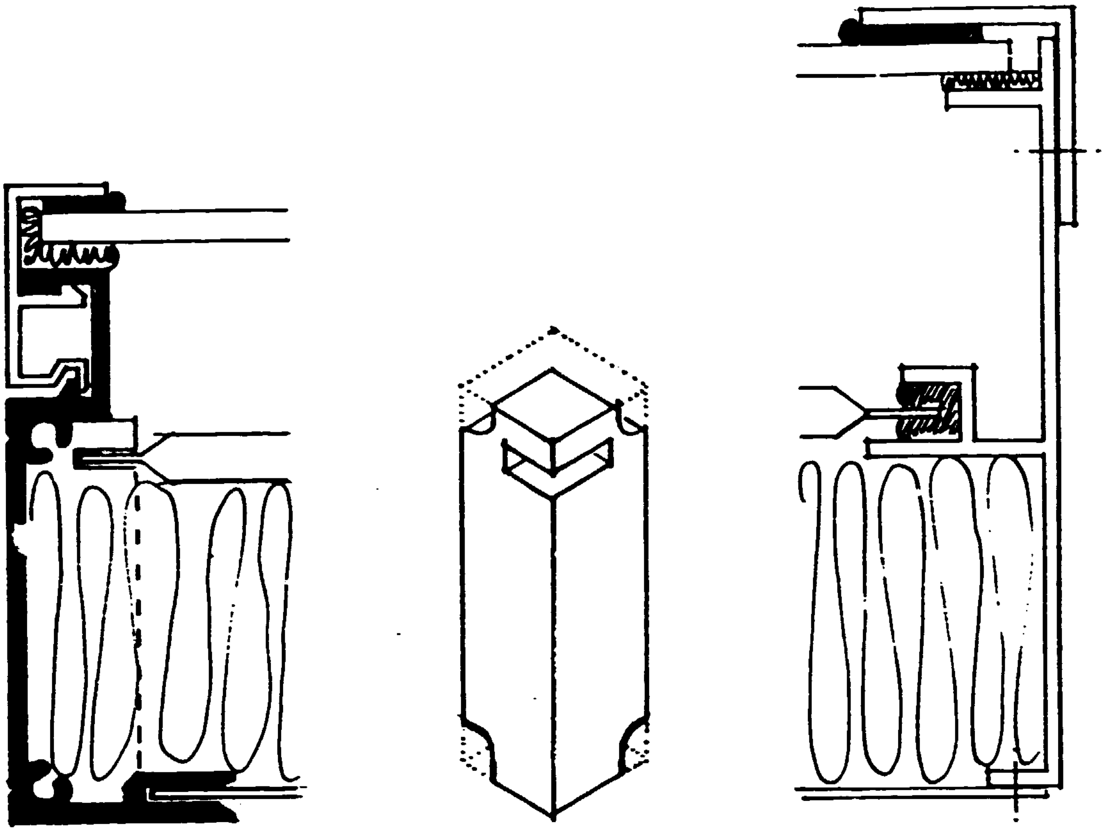
First a climatic data file for Damascus has been constructed (Fig.9). (For RH mean values were only available, from which the am. and pm. values were estimated. The standard deviations of temperature were also only estimated.)
The program was then used to predict the performance and annual energy contribution of two different systems.

(1) The standard domestic unit, two collectors of 2 m² each, a 220 L H/W tank and a cold water cistern, all mounted on a steel stand.
(2) A hypothetical system named TEST1, which consists of 10 collectors of a total of 20 m² area (Fig.12). The components of this system are listed in Table 2 and priced.

TABLE 2 Components and costs for the TEST1 system

collectors	10	SP 7200	SP 72 000	
tank, insulated, one jacket	1		8 500	
- two jackets	1		10 500	
pump	1		3 500	
motorised 3-way valve	1		22 000	
expansion tank (incl. nitrogen)	1		1 000	
glycol	25 L	SP 50/L	1 250	
insulated pipes, 20 mm	25 m	225/m	5 625	
- 25 mm	10 m	280/m	2 800	
air release valve	2	200	400	
differential thermostat	1		3 500	
T and L fittings	47	18	846	
valves, 20 mm	4	75	300	
- 25 mm	9	120	1 080	
support frames	12	300	3 600	
flexible connections	20	45	900	
+ 30% overheads			137 801	179 142
delivery			2 000	
vertical transport			2 000	
installation labour	112 h		5 600	
incidental materials			200	
+ 30% overheads			9 800	12 740
TOTAL				SP 191 881

say SP 192 000 / 20 m² = SP 9600/m²



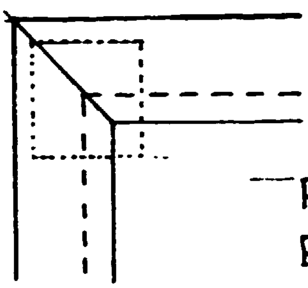


FIG. 8

PROPOSED EXISTING

EXTRUDED AL. COLLECTOR FRAME

Climatic data for DAMASCUS
Latitude = 33.5

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TMax:	12.0	14.0	17.0	22.0	28.0	33.0	35.0	36.0	32.0	27.0	20.0	14.0
TMin:	2.0	3.0	5.0	8.0	13.0	16.0	17.0	17.0	15.0	12.0	8.0	4.0
Tsd:	1.8	2.2	2.3	2.6	2.8	3.2	3.6	3.8	3.2	2.8	2.2	1.8
RHam:	80	70	60	50	45	35	40	40	45	50	65	75
RHpm:	70	60	50	40	35	25	30	30	35	40	55	65
Rain:	50	25	25	25	10	0	0	0	0	10	25	25
Irad:	2750	3910	5020	6210	7450	8250	8180	7520	6360	4820	3510	2700

FIG. 9

DAMASCUS CLIMATIC DATA

DATA PREPARATION

FIG. 10.

ACTSYS

job name		:	STANDARD
location		:	DAMASCUS
system type		:	H/W only
collector	orientation	:	180°
	tilt	:	5°
	area	:	m^2
	constant 'a'	:	0.86
	constant 'b'	:	8.6
	glazing	:	single
	flow rate	:	0.06 L/s
tank	volume	:	220 L
	connection	:	heat exch.
heat exch.	type	:	coil-in-tank
	transfer area	:	1.65 m^2
	flow rate	:	0.05 L/s
hot water	consumption	:	200 L/day
cold water	temperature	:	$= \bar{T}_o$ (monthly)
thermostat	set point	:	55°

ACTSYS

job name		:	TEST 1
location		:	DAMASCUS
system type		:	H/W only
collector	orientation	:	180°
	tilt	:	35°
	area	:	20 m^2
	constant 'a'	:	0.86
	constant 'b'	:	8.6
	glazing	:	single
	flow rate	:	0.3 L/s
tank	volume	:	1300 L
	connection	:	heat exch.
heat exch.	type	:	coil-in-tank
	transfer area	:	4 m^2
	flow rate	:	0.3 L/s
hot water	consumption	:	900 L/day
cold water	temperature	:	$= \bar{T}_o$ (monthly)
thermostat	set point	:	60°C

Solar performance calculations by the f-chart method
for DAMASCUS job name: test1
for a domestic hot water system

latitude = 33.50 deg.
daily H/W use = 900 lit.
tank volume = 1300 lit.
collector area = 20.00 m2.
\- tilt = 35 deg.
\- orientation = 180 deg.
\- constants : a = 0.79 b = 7.92

months :	1	2	3	4	5	6	7	8	9	10	11	12	Total
mean temperature :	7.0	8.5	11.0	15.0	20.5	24.5	26.0	26.5	23.5	19.5	14.0	9.0	
irradiation (Wh/m2):	4229	5265	5785	6160	6664	7001	7064	7064	6845	6095	5231	4372	
daily H/W load(kWh):	55	54	51	47	41	37	35	35	38	42	48	53	16336
daily solar contrib:	28	35	37	37	35	32	32	31	33	34	32	28	12014
solar fraction :	0.51	0.66	0.73	0.78	0.84	0.88	0.89	0.89	0.87	0.79	0.67	0.53	0.74

Solar performance calculations by the f-chart method
for DAMASCUS job name: standard
for a domestic hot water system

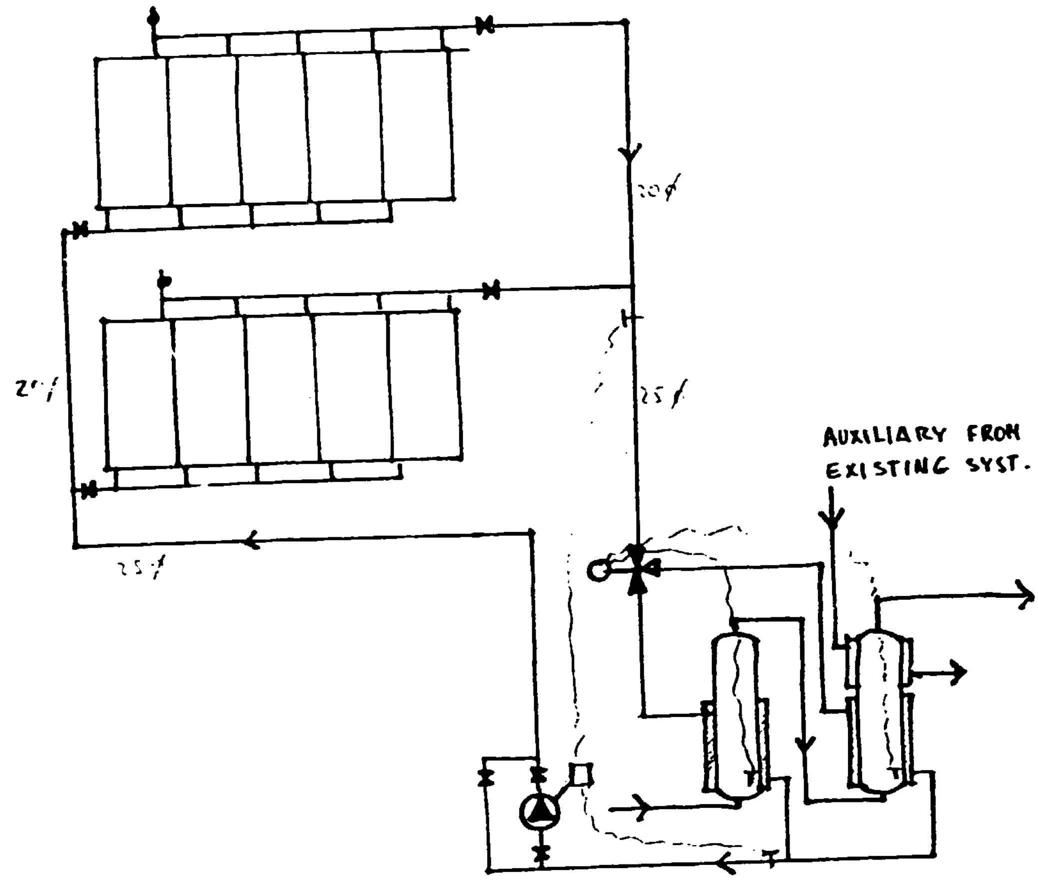
latitude = 33.50 deg.
daily H/W use = 200 lit.
tank volume = 220 lit.
collector area = 4.00 m2.
\- tilt = 45 deg.
\- orientation = 180 deg.
\- constants : a = 0.79 b = 7.92

months :	1	2	3	4	5	6	7	8	9	10	11	12	Total
mean temperature :	7.0	8.5	11.0	15.0	20.5	24.5	26.0	26.5	23.5	19.5	14.0	9.0	
irradiation (Wh/m2):	4435	5381	5709	5843	6139	6349	6437	6592	6629	6143	5450	4624	
daily H/W load(kWh):	11	11	10	9	8	7	7	7	7	8	10	11	3207
daily solar contrib:	6	7	7	7	6	6	6	6	6	7	7	6	2356
solar fraction :	0.55	0.68	0.73	0.75	0.79	0.82	0.84	0.87	0.87	0.81	0.71	0.58	0.73

FIG. 11

EXAMPLE OUTPUTS: ACTSYS

A HYPOTHETICAL SYSTEM DESIGN (TEST 1) FIG. 12.



Daily consumption		900 L @ 60°C
2 tanks @	650 L	1300 L
10 collectors @	$2\ m^2$	$20\ m^2$
flow rate	$20 \times 0.015\ L/s.m^2$	0.3 L/s

Comparisons

	STANDARD	TEST1
No. of collectors	2	10
collector area	4 m^2	20 m^2
tank volume	220 L	1300 L
daily H/W use	200 L	900 L
annual energy requirement	3207 kWh	16336 kWh
solar fraction	0.73	0.74
solar energy contribution	2356 kWh	12014 kWh
cost, as supplied	SP 27 200	SP 179 141
installation	4 800	12 740
total	SP 32 000	SP 191 881
annual saving: electricity*	SP 1296	SP 6608
simple payback period	25 years	29 years
annual saving: oil #	-	SP 4645
simple payback period	-	41 years

* electricity SP 0.55/kWh
\# oil SP 2.75/L Calorific value 9.35 kWh/kg Boiler efficiency 75%
2.75 / (9.35 x 0.75) = 0.39 SP/kWh

The criterion for an investment decision, using the simple (crude) payback method is

$B \times y > C$ where B = benefit (annual)
y = number of years of expected life
C = capital cost

In the best of the above cases (DHW system, replacing electricity):
B = 1296
y = 12
C = 32 000

1296 x 12 >? 32000
15552 < 32000 therefore the system is economically not feasible.

Using a discounted cash-flow method, in the above criterion 'y' is replaced by F, the 'present worth factor':

$$B \times F > C \qquad F = \frac{1 + f + r}{i - f}\left[1 - \left(\frac{1 + f}{1 + i}\right)^{y}\right]$$

provided that $i > f$ where i = interest rate
f = inflation rate
r = energy cost increase above i
assuming i = 0.09 (9%)
f = 0.08
r = 0.10 and y = 12

$$F = \frac{1.18}{0.01}\left[1 - \left(\frac{1.08}{1.09}\right)^{12}\right] = 12.36$$

1296 x 12.36 >? 32000
16018 < 32000 therefore the system is economically not feasible.

The system would be feasible if

(a) the capital cost were reduced by half, or
(b) the cost of energy (electricity) were doubled, or
(c) a subsidy or other benefit were offered to the extent of 50% of cost

- or some appropriate combination of these measures,

eg. for the DHW system:

(a) the collector is improved by 10% to give 2592 kWh solar contribution, which (replacing electricity) is valued at SP 1425
(b) interest rate is increased to 17%
the inflation rate is 16%
energy cost increase above inflation is 23%
(c) the capital cost is reduced by 20% (from 32 000) to SP 25 600
(d) a 30% subsidy (or tax benefit) is provided, ie 7 680

resulting in a net capital cost of SP 17 920

then

$$F = \frac{1.39}{0.01}\left[1 - \left(\frac{1.16}{1.17}\right)^{12}\right] = 13.6$$

1425 x 13.6 >? 17920
19380 > 17920 therefore the system is economically feasible.

11. DUAL ACCOUNTING

In the particular situation of Syria, it may however be possible, that the system would show a positive balance in terms of hard currency, whilst running into deficit in a local currency account. From the national point of view this may be an acceptable result. An attempt is therefore made to separate the hard currency (US \$) component, ie. the cost of imported raw materials, from the costs of labour and local materials (in SP). The benefit, the saving of fuel oil, is priced in hard currency (US \$).

	hard currency	local currency
Collector:		
(1) tube grid + plate:		
21 kg x \$0.575 =	\$ 12.30/m²	SP 3600-(12.30 x 40) = SP 3108/m²
(2) pressed steel:		
12.5 kg x 0.575 =	7.18/m²	(\$37.5-7.18) x 40 = 1213/m²
Tank:		
161 000 kg/1500 = 107		SP 19000/20 = 950
107 kg x \$0.575/4 m² =	15.43/m²	950 -(15.43 x 40) = 338/m²
Rest of system:		
deducting from the total the cost of absorbers,		
tank and deleting the 3-way valve:		
[191 881-(72000+19000+22000)]/20= SP 3944		
for valves, pipes, etc.	\$ 15 / m²	3944 -(15 x 40) = 3344/m²

	Tube-grid+plate	Pressed steel
Total system cost	\$ 42.73 + SP 6790/m²	\$ 37.61 + SP 4895/m²
Annual benefit	879 kWh/m²y	924 kWh/m²y
	\$ 8.79 / m²	\$ 9.24 / m²
12-year benefit	\$ 105.48 / m²	\$ 110.88 / m²
\$ benefit converted	SP 4219 - 6790	SP 4435 - 4895
net 12 year result	- SP 2571/m²	- SP 460/m²

12. SOLAR SYSTEMS

Solar energy can be converted to as useful form by many different systems and those relevant to Syria are suggested to be the following:

- domestic hot water (DHW) systems
- industrial process heating systems
- space heating (by water- or air-) systems
- drying
- space cooling
- refrigeration
- photovoltaic systems.

The main emphasis of the present report is on DHW systems, as these are the most widely used. The collectors produced for DHW systems can also be used for industrial process heating and space heating purposes. These will now be examined.

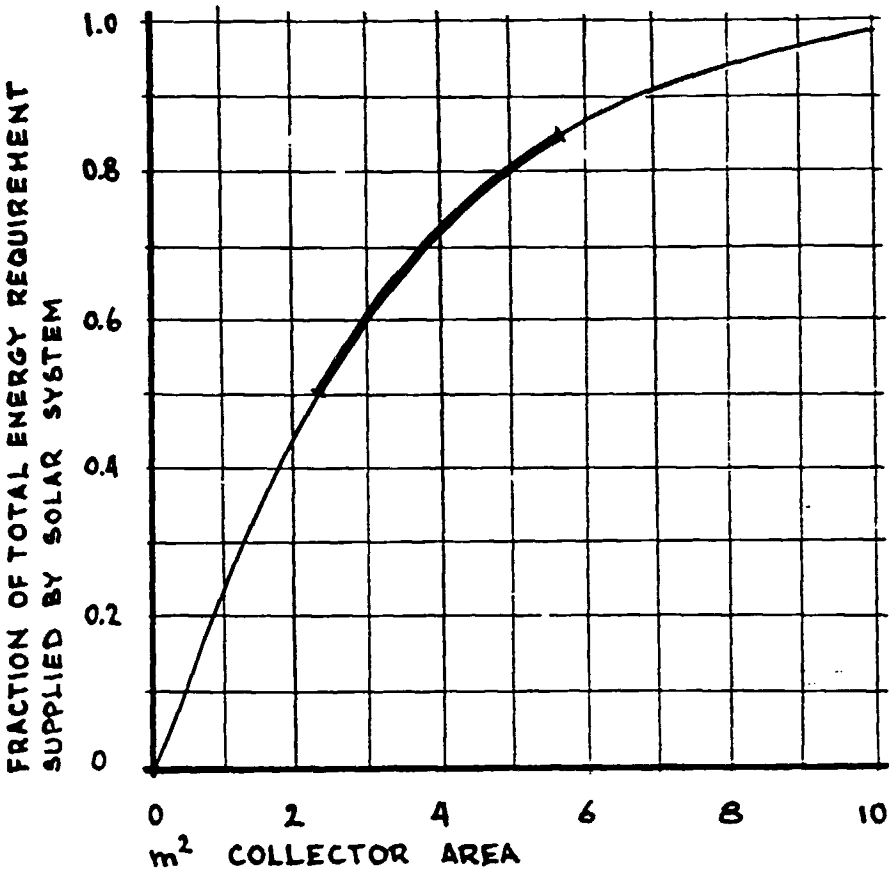
12.1 Industrial process heating

Industrial processes that require hot water at temperatures attainable by solar heating demand a high degree of reliability, thus an exclusively solar system is not possible. In most cases an existing boiler system can be retained as an auxiliary and standby system. The best economic returns can be achieved when the solar fraction is less than about 0.5, as shown for the generalised case in Fig.13, which is a particular example of the law of diminishing returns. The system most likely to succeed in economic terms would be a pre-heater, producing 40 - 50 °C water. At such temperatures quite high collection efficiencies can be achieved. Eg. the new model collector of the Solar Energy Factory, with (say) 800 W/m² irradiance and 25°C air temperature would give the following efficiencies:
at 90°C 0.17; at 65°C 0.42; at 40°C 0.68

In principle the system is not different from a DHW system, only increased in size and in that a thermosiphon system is normally not possible, pumping must be used. It may be an additional benefit that, in some instances, an existing tank may be used for the purposes of the solar system.

Similar considerations apply to steam generating plants, where significant energy savings can be achieved by pre-heating the make-up water with a solar system. A particular example of this is discussed in Appendix 5.

FIG. 13.



$F' = 0.91$
$(\tau\alpha)_e = 0.71$
$U' = 4.00\ W/m^2\,°C$

SOLAR FRACTION, AS A FUNCTION OF COLLECTOR AREA

FOR A DOMESTIC HOT WATER SYSTEM

12.2 Space heating

Domestic scale active space heating systems are little more than enlarged versions of a DHW system. The form of heat emitter is a subject of choice, it may be eg. a fan-coil unit, a panel radiator or an embedded coil floor warming system. Some systems in Europe and North America work quite satisfactorily, but their economics is marginal. It is suspected that in Syria, where the winter is milder and shorter, thus for more than half a year the system would not be utilised at all, the economics would be even less favourable.

In order to verify this, a small, 2-storey house has been selected (similar to the 2000 houses built in the Solar Village, near Damascus airport) and its heating requirements calculated (Appendix 6). That design is based on a floor warming system, which uses high density polyethylene (or polybutyl) pipes arranged in five separate loops. The coils would be laid at a pitch of 200 mm, except in areas to be covered by built-in furniture (or likely to be covered by other furniture).

This is the system offering the greatest probability of success, for two main reasons:

(1) the low temperature operation (30 - 35°C) allows a high collection efficiency

(2) the fabric of the building can be relied on to assist in thermal storage, thus the storage tank can be quite small.

A more convincing application is the use of passive solar heating systems. Two main types may be considered:

(1) direct gain systems

(2) mass wall (Trombe-Michel wall) systems.

The direct gain system consists of large, equatorially oriented windows and adequate absorption surfaces and building mass to store the absorbed heat. This system produces the highest efficiency, but there is a risk of overheating if the building mass is insufficient.

The mass wall system consists of a heavy masonry wall, painted dark and glazed externally, to enclose an air gap. The convective version has vent openings to the room at top and bottom. As the dark surface absorbs the radiation, the air in this gap will be heated and rise, entering the room at the top and drawing in room air at the bottom, thus generating a convective loop. This gives an instantaneous heat gain (whilst there is a solar input). If the vents are closed, or there are no vents, the heat will be absorbed in the mass wall and then transmitted to the room with a time delay depending on the wall mass. This system is very useful where the building is otherwise lightweight. If the purpose is heating during the daytime, then the convective mass wall cannot compete with the direct gain system.

As most buildings in Syria are of heavy masonry and concrete construction, reliance on direct gain systems would be strongly recommended. Non-convective mass walls may be employed to a limited extent, to boost the night time heating, in continuously occupied buildings, but the use of convective mass walls is not recommended.

One point which must not be forgotten is the summer shading of direct gain windows, or else quite severe summer overheating problems may be created.

Table 3 below summarises the results of calculations in Appendix 6. Starting with the original 24 664 kWh annual heating requirement, there are two basic options:

a) An active system, costing some SP 104 000, which could provide 13 500 kWh of heat in a year, leaving an auxiliary heat requirement of 11 164 kWh

b) A very modest rationalisation of the building itself: a semi-passive, direct gain system, costing very little (if anything) above the normal building cost, which would give a solar contribution of almost 10 000 kWh, reducing the heating requirement to 14 745 kWh. A smaller active system, costing some SP 65 000 could provide 7950 kWh of heat in a year, leaving an auxiliary heat requirement of 6800 kWh only.

TABLE 3 — Contribution of solar space heating systems

	ORIGINAL	SEMI-PASSIVE
passive contribution		9 919 kWh
heating requirement	24 664 kWh	14 745 kWh
active system:		
- collectors	32 m^2	20 m^2
- tank	1800 L	1200 L
- solar fraction	0.58	0.54
- solar contribution	13 500 kWh	7 950 kWh
auxiliary requirement	11 164 kWh	6 795 kWh

13. TRAINING

Factory workers can be trained 'on the job'. It is the foremen, technicians and installers who must have an understanding how the system as a whole works and could therefore greatly benefit from a training course. Professional engineers and architects would also need to attend a short training course, to familiarise themselves with solar/thermal systems.

In both cases the minimum requirement would be a two-week full time course.

It is suggested that during July - August of 1990 two training courses should be organised by the GOEI:

1. Participants: design professionals: engineers and architects,
   Max. number: 20
   Duration: 2 weeks, full time
   Format: 1 week lectures, with short exercises
   (4 - 5 lectures per day + 3 - 4 hours of exercise work with individual or group tutorials)
   1 week project work
   (with individual or group tutorials)
   Content: both active and passive solar heating systems, emphasis on specific solar system design methods, including the use of various computer programs, both their background theory and hands-on experience.
   Award: Certificate of solar/thermal design
   Contributors: some 50% of the lecture input and tutorial assistance by the writer, the other 50% from local experts

2. Participants: technicians, installation supervisors, foremen
   Max. number: 20
   Duration: 2 weeks, full time
   Format: 1 week lectures, seminars and exercises
   1 week case studies and practical workshop and site experience
   Content: primarily active solar heating systems, with some brief reference to passive systems
   Award: Certificate of solar/thermal technology
   Contributors: some 30% of lecture input and associated tutorial assistance by the writer, the remaining 70% from local experts; the practical content is organised locally

Appendix 1
PERSONS CONSULTED / CONTACTED

UNIDO/UNDP	Dr.Bachaan, deputy resident
	Dr.Khaled Alloush, programme director
	Ms.Nadya Kozak, programme liaison officer
	Mme.Bayazid, admin.
GOEI	Mr.Mandooh Munajed, director general
	Mr.Ismat Khankan, technical advisor
	Mr.Abd-el-Hafiz Dalati, director, feasibility studies
SSRC/HIAST	Dr.Abd-el-Hadi Zein
	Dr.Soulayman Soulayman
METALCO	Mr.Anwar Kassam, techn.manager, Adra
	Mr.Jamil Ezzaldin, eng. manager, Solar Factory
	Mr.Akil Khorzom, eng. techn.manager, Solar Factory
ITRC	Mr.Taufik Sheikh-el-Sahab, acting director
Textile Factory	Mr.Abdul Halim, technical manager
	Ms.Sarah Kekheya, eng.
	Mr.Hassan Horea, factory manager
	Mr.Jakob Fayomee, factory technical manager
REC/REO	Dr.M.Kordab, chairman/director
Others	Mr.Hassan Assidi, technical services manager, Damascus Province
	Mr.Ali al Kurdi, architectural eng. MILIHOUSE
	Mr.Said Aljarrah, Uni.of Damascus.

Appendix 2
DTCD PROJECT

Derek Lovejoy, interregional adviser, visited Syria last September-October and produced a report in October 1988 to the Department of Technical Cooperation and Development (DTCD), which embodies the project plan for SYR/88/007: 'Development of renewable energy'.

Originally developed to a total cost of $ 698 000, but it is likely to be reduced to $ 500 000 (probably the 100 kW, grid-connected wind generator proposed for Qunetra will be removed). The project is seen as consistent with the UN 1981 Nairobi Conference resolutions.

Main components:
- improve solar radiation measurements, produce solar atlas
- wind survey: (a) general, (b) 2 - 3 sites in detail
- 10 kW stand-alone wind generator pumping system
- 10 kW PV village electrification project
- 5 - 10 rural biogas systems
- one large solar industrial H/W demonstration project (collectors local, accessories to be funded).

Primary counterpart: Ministry of Electricity,

Coordinator: Dr.Kordab, ORE, Prime Minister's Department

Appendix 3
SYRIAN SOLAR STANDARDS

The following solar-related Syrian standards have been issued:
(The main title of each is 'Solar water heating systems for domestic use', sub-titles only are listed below)

SNS 637,P(1)/1988	- the systems, pt.1: installation requirements
SNS 637,P(2)/1988	- the systems, pt.2: performance and methods of test
SNS 637,P(3)/1988	- outdoor performance and test methods for thermosiphoning systems
SNS 651/1988	- terms, definitions, symbols and units.
SNS 652,P(1)/1988	- thermal storage tanks, pt.1: materials
SNS 652,P(2)/1988	- thermal storage tanks, pt.2: manufacturing requirements
SNS 652,P(3)/1988	- thermal storage tanks, pt.3: performance and methods of test
SNS 652,P(4)/1988	- thermal storage tanks, pt.4: name plate
SNS 653/1988	- accessories, elements, materials and manufacturing requirements

As these are only available in Arabic, the writer was unable to read them, but assurance was given that they largely follow the ASHRAE standards.

Appendix 4
THE CISE REPORT

A Milano-based company, CISE (Centro Informazioni Studi Esperienze) conducted a major study into 'Solar Energy Manufacturing' in 1986, for the Scientific Studies and Research Centre (SSRC). The study was sponsored by the EEC and associate consultants were CUEIM (Consorzio Universitario Economica Industriale e Manageriale) and Phoebus Recerche per l'energia solare spa.

Their report under the same title was presented to SSRC in April 1986, in four volumes (A4). Volume 1 is a 70 p. summary of the other three volumes, which total 620 pages.

The report includes extensive statistics, a review of existing solar energy technologies and a - somewhat tentative - estimate of the likely market. It is found that several statements are erroneous and the prices on which their economic studies are based are already grossly out of date. A summary of their market estimate follows.

Market estimate (1986)

	NOW	year 2000
Dwellings: population	12 million	17 million
dwelling units	1.7 million	+0.6 million
suitable for solar H/W	30%	80%
	510 000	+480 000
possible, considering income	158 000	+75 - 268 000

Other buildings:
hotels: 50 - 100 medium grade (1st, 2nd class) are potential users
hospitals: 700 - 1200 standard systems (>11000 beds in 182 hospitals)
health centres: over 500 centres, could have 1200 standard systems
colleges, barracks, prisons, restaurants = ? (no data)

	LOW	HIGH
Industrial:		
H/W systems	50 units	200 units
hot air systems	60 units	250 units

each 'unit' may involve 100s of m² of collectors.

Photovoltaics:

villages with less than 100 people	1000	(>20 kW)
telecommunications	300	(150 - 300 W)
small radio repeaters	3000	(20 W)

In estimating collector production, the report is very optimistic. The 1986 production is estimated as 6400 collectors and further increases (up to 9600 per year) are predicted. It would appear that the largest of the 6 factories listed has closed down, some of the private ones concentrate on other business and only produce a few units and the production of the state-owned Solar Energy Factory is practically nil in 1988, due to a total lack of materials.

The report suggests that in the next few years the market is likely to be 27 000 - 28 000 m^2 flat plate collectors per year. A further growth is expected in demand and the report recommends the setting up of another factory (Aleppo is the proposed location), with 15 000 m^2 annual production capacity.

In the present writer's opinion this is the 'expert report' which gives a bad name to such reports. It is heavily padded with data and statistics, often of doubtful accuracy and relevance. It is very neatly presented, it is a polished piece of work, appears to be an aim in itself, but completely failing to recognise the realities of the situation and because of that it will remain totally inconsequential.

Appendix 5

AN INDUSTRIAL PROCESS HEATING SYSTEM

The Oriental Underwear Co. (see Fig.14)

The Office of Renewable Energy suggested a system for this factory to provide 25 m^3 H/W per day. The writer proposed a pre-heating system to give a T of 25 K, eg. from 20 to 45 °C. The daily heat requirement would thus be: 25 m^3 x 1.16 kWh/m^3K x 25 K = 725 kWh

Winter irradiation at 45° tilt is some 4.5 kWh/m^2day. Assuming an efficiency (for such low temperatures) of 0.45, this would give 2 kWh/m^2 useful heat, thus the necessary collector area would be around 725/2 = 362 m^2.

A visit to the factory revealed the following:
each of the three fire-tube boilers produces 4 tonnes of steam per hour (consuming 4 m^3 of water). The factory works three shifts, but the night shifts only use one boiler, thus the daily steam production in tonnes (= water consumption in m^3) is

3 boilers x 4 t/h x 8 h = 96 t
1 boiler x 4 t/h x 16 h = 64 t
-----
160 t

Approx. 10% of this is returned as condensate, ie. some 16 m^3, which is then mixed with 144 m^3 of cold water in the make-up water tank. The wet steam is used for dyeing, bleaching, pressing and in winter also for space heating through heating coils built into the evaporative air conditioning system.

The daily heat requirement is: 144 x 1.16 x 25 = 4176 kWh
giving an area requirement of 4176 / 2 = 2088 m^2
so the system is likely to be around 2000 m^2.

As the diagram (Fig.14) indicates, the required 1000 collector panels could be positioned as follows:

(1) The approx. 40 x 60 m area of the factory which has a saw-tooth roof: each of the 5 sections (some 12 m spacing) could accommodate 2 rows of 40 collectors, ie. 2 x 40 x 5 = 400 collectors.
(2) The approx 20 x 60 m roof of the single storey service building could accommodate 17 rows of 20 collectors = 340 collectors.
(The mid-winter noon solar altitude is 90 - 31.5 - 23.5 = 31°
With 35° collector tilt the spacing must be a minimum of
s = h/tan(31) where h = 2 m x sin(35) = 1.15, therefore s = 1.91 m
thus the overall row spacing is 3.55 m, which allows 17 rows in the 60 m length)
(3) The boiler house roof (15 x 14 m) could provide space for 4 rows of 14 collectors = 56 collectors.

A further 204 collectors must be accommodated. There is more than ample space available on the flat roof of the main factory building. The problem with this roof slab is that (apparently) bauxite cement has been used for the concrete mix. Beams have developed typical shear cracks and had to be fitted with externally applied flat bar stirrups in the maximum shear zone. Arrangements must be made for an inspection and structural evaluation of the roof slab.

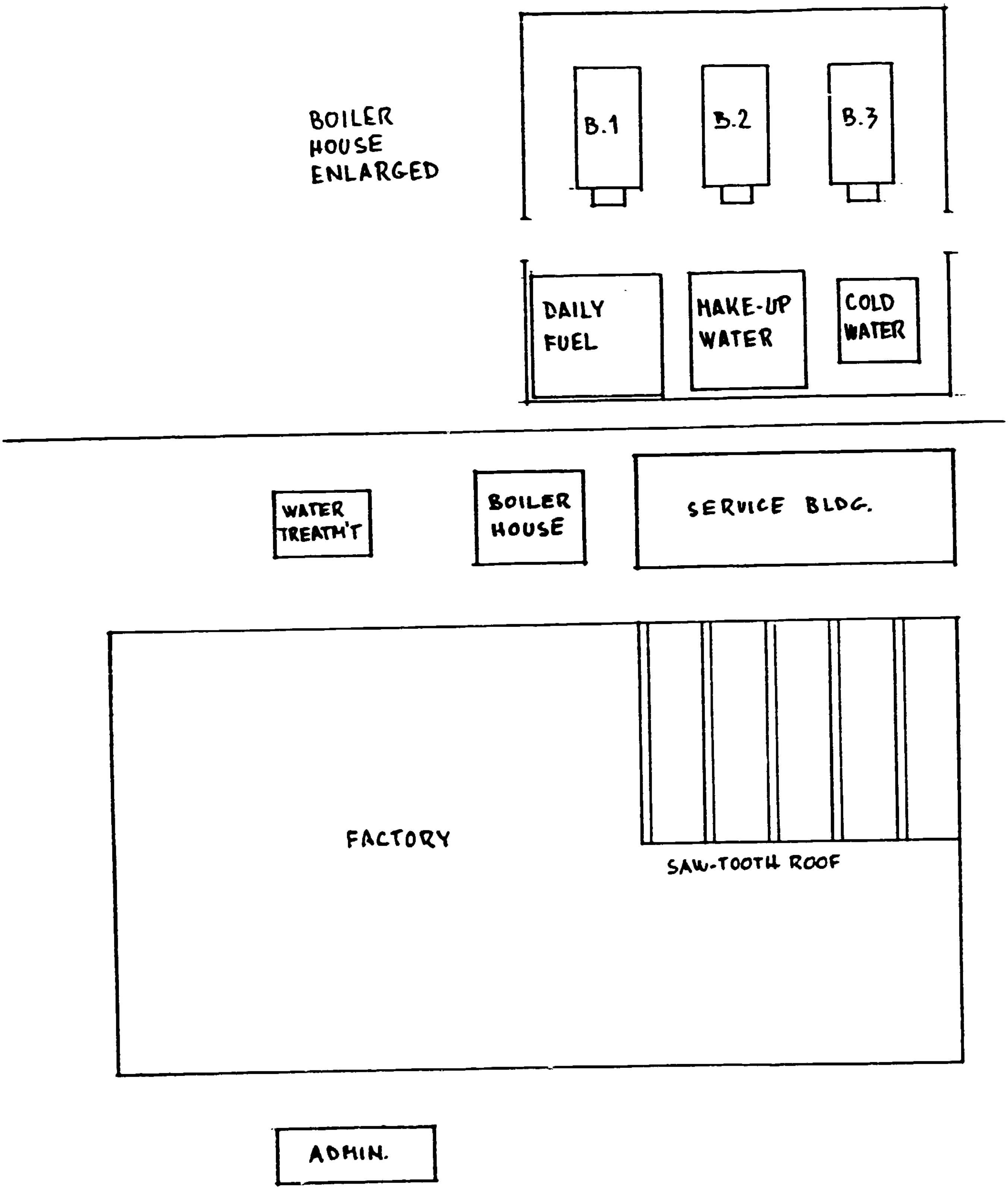


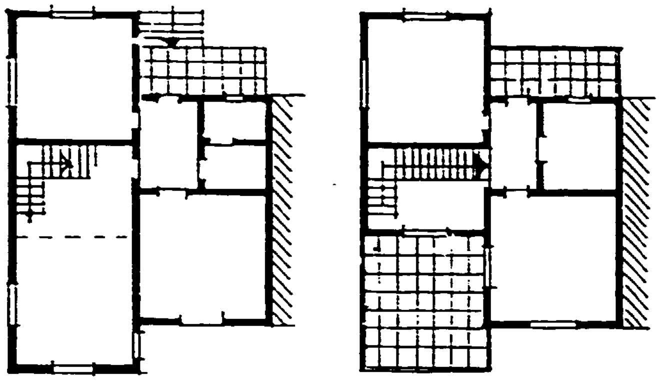
FIG. 14.

THE ORIENTAL UNDERWEAR CO.

Appendix 6

A TYPICAL HOUSE: HEATING REQUIREMENTS

The plans below describe a small (91 m²) two-storey house, which is the end-unit of a row of terraces.



GROUND FLOOR　　UPPER FLOOR

The walls are concrete blocks, rendered, the floors and roof are reinforced concrete slabs, the windows are single glazed in aluminium frames. The heat loss calculation below (a printout of the QBALANCE program) shows that the specific heat loss rate of the house is some 734 W/K and that the annual heating requirement is about 24 600 kWh.

Job: VILLAGE1. - Location: DAMASCUS　　month: JAN.

	No 1	ORI 2	Len 3	W/H 4	A 5	grp. 6	code 7	U 8	A.U 9	sgf 10	Rso 11	abs 12	Gav 18	Qs 19
1:	10	-1	7.80	7.20	56.16	4	32	0.79	44.2	-	-	-	0	0
2:	20	270	9.00	5.20	38.52	2	28	2.76	106.3	-	0.06	0.40	69	175
3:	21	270	6.90	1.20	8.28	1	30	6.00	49.7	0.76	-	-	69	432
4:	30	180	7.20	5.20	28.48	2	28	2.76	78.6	-	0.06	0.40	154	291
5:	31	180	5.60	1.60	8.96	1	30	6.00	53.8	0.76	-	-	154	1050
6:	40	360	7.20	5.20	28.08	2	28	2.76	77.5	-	0.06	0.40	31	57
7:	41	360	5.70	1.20	6.84	1	30	6.00	41.0	0.76	-	-	31	160
8:	42	360	1.20	2.10	2.52	2	91	2.44	6.1	-	0.06	0.70	31	8
9:	50	-1	7.80	7.20	56.16	3	00	2.02	113.2	-	0.04	0.80	113	93

volume = 246.0 m3　　(W/K) qc = 570.5　　(W) 2266

air ch.= 2.0　　qv = 164.0　　Qi = 350

q = 734.5　　Qs+i = 2616

	Des.temp degC	Gains W	Balnce pt degC	Deg.hrs K.h	heating kWh
JAN:	19.8	2616	16.2	6851	5031.9
FEB:	20.2	3171	15.9	4985	3661.3
MAR:	21.0	3622	16.1	4129	3033.0
APR:	22.2	3995	16.8	3441	2527.4
MAY:	24.0	4419	17.9	2041	1499.1
JUN:	25.2	4748	18.7	0	0.0
JUL:	25.7	4733	19.2	0	0.0
AUG:	25.8	4581	19.6	0	0.0
SEP:	24.9	4209	19.2	0	0.0
OCT:	23.6	3808	18.5	2904	2133.1
NOV:	21.9	3159	17.6	3502	2572.6
DEC:	20.4	2713	16.7	5726	4205.7
TOT:				33579	24664.1

If an active solar heating system were installed, with 32 m² collectors and an 1800 L tank serving an embedded coil floor warming system, this would provide a solar fraction of 0.58, or an annual energy contribution of some 13 500 kWh. If this were to replace electric heating, its value would be SP 7425 per year. Replacing oil in an oil-fired central heating system, its value would be SP 5192. The installation cost of this system may be (3265 x 32 =) SP 104 480, giving a crude pay-back period of 14 or 20 years respectively.

If the house design is modified, to turn it into a very simple passive solar house (only minor rationalisation), by increasing the size of south-facing windows, double glazing [illegible] windows, slightly improving the wall insulation, the specific heat loss rate would be reduced to about 610 W/K, the heating season from 8 to 6 months and the annual heating requirement to some 15 000 kWh. This means that the passive solar measures would have saved almost 10 000 kWh, with very little extra expense.

Job: village2. - Location: DAMASCUS month: JAN.

No 1	ORI 2	Len 3	W/H 4	A 5	grp. 6	code 7	U 8	A.U 9	sgf 10	Rso 11	abs 12	Gav 13	Qs 19
1: 10	-1	7.80	7.20	56.16	4	32	0.73	44.2	-	-	-	0	0
2: 20	270	9.00	5.20	38.52	2	29	1.93	74.3	-	0.06	0.40	69	123
3: 21	270	6.90	1.20	8.28	1	35	3.60	29.8	0.64	-	-	69	364
4: 30	180	7.20	5.20	18.54	2	29	1.93	35.8	-	0.05	0.40	154	132
5: 31	180	9.00	2.10	18.90	1	35	3.60	68.0	0.64	-	-	154	1864
6: 40	360	7.20	5.20	28.08	2	29	1.93	54.2	-	0.06	0.40	31	40
7: 41	360	5.70	1.20	6.84	1	35	3.60	24.6	0.64	-	-	31	135
8: 42	360	1.20	2.10	2.52	2	91	2.44	6.1	-	0.05	0.70	31	8
9: 50	-1	7.80	7.20	56.16	3	00	2.02	113.2	-	0.04	0.80	113	93

volume = 246.0 m3 (W/K) qc = 450.2

air ch.= 2.0 qv = 164.0

q = 614.2

(W) 2759

Qi = 350

Qs+i = 3109

	Des.temp degC	Gains W	Balnce pt degC	Deg.hrs K.h	heating kWh
JAN:	19.8	3109	14.7	5735	3522.7
FEB:	20.2	3662	14.3	3881	2384.1
MAR:	21.0	4007	14.5	3577	2197.4
APR:	22.2	4139	15.4	3276	2012.4
MAY:	24.0	4499	16.6	0	0.0
JUN:	25.2	4762	17.4	0	0.0
JUL:	25.7	4769	17.9	0	0.0
AUG:	25.8	4731	18.1	0	0.0
SEP:	24.9	4569	17.4	0	0.0
OCT:	23.6	4314	16.6	0	0.0
NOV:	21.9	3732	15.9	3006	1846.6
DEC:	20.4	3258	15.1	4528	2781.4
TOT:				24005	14744.7

A lesser size active solar heating system could still be introduced, say 20 m² of collectors and an 1200 L tank, which would give a little over half of the remaining heating requirement, about 8000 kWh in a year. This may be valued at SP 4400 or SP 3078, if replacing electricity or oil respectively. The installation cost may be around SP 65 300, giving a pay-back period of 15 years or 21 years respectively.

Appendix 7

CLIMATIC DATA FOR SOME SYRIAN LOCATIONS

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
DAMASCUS (airport)	T.av (°C)	6.1	8.1	11.3	15.7	20.2	24.5	25.2	25.9	22.9	18.2	11.8	7.4
Lat: 33.42°	sun hours	5.4	6.8	7.7	8.4	10.7	11.9	12.0	11.8	10.4	9.0	7.2	5.3
Lon: 36.51°	G (Wh/m²)	2778	3778	4778	5722	6917	7477	7417	7000	5917	4639	3417	2589
KHARABO	T.av (°C)	6.3	7.7	11.3	15.2	19.1	23.3	25.0	24.7	22.0	17.5	11.9	7.3
Lat: 33.49°	sun hours	5.1	6.7	7.7	8.6	10.5	12.3	12.3	11.8	10.5	9.3	7.3	5.3
Lon: 36.23°	G (Wh/m²)	2717	3778	4833	5833	6917	7439	7583	7083	6000	4750	3444	2606
PALMYRA	T.av (°C)	6.8	8.9	12.8	17.7	22.9	27.3	29.3	29.1	25.9	20.6	13.2	8.1
Lat: 34.55°	sun hours	5.3	6.9	7.7	8.5	10.4	12.2	12.5	11.8	10.5	8.7	7.3	5.6
Lon: 38.30°	G (Wh/m²)	2642	3667	4667	5639	6722	7472	7500	6917	5833	4444	3305	2550
HAMA	T.av (°C)	7.3	8.3	11.8	16.3	21.5	26.0	28.1	28.2	25.3	20.3	13.5	8.2
Lat: 35.13°	sun hours	4.2	5.5	7.1	8.4	10.7	12.5	12.7	12.0	10.5	8.5	6.9	4.5
Lon: 36.75°	G (Wh/m²)	2339	3278	4500	5667	6889	7639	7639	7028	5861	4389	3194	2269
LATTAKIA	T.av (°C)	11.6	12.6	15.1	17.9	20.9	24.0	26.4	26.9	25.6	22.6	17.8	13.2
Lat: 35.50°	sun hours	4.7	5.8	6.4	7.3	9.9	10.7	10.3	10.3	9.5	7.9	6.7	4.8
Lon: 35.78°	G (Wh/m²)	2361	3222	4111	5083	6389	6806	6611	6278	5361	4056	3000	2233
ALEPPO	T.av (°C)	5.6	7.4	10.7	15.5	20.9	25.7	28.1	28.1	24.9	19.5	12.3	7.3
Lat: 36.18°	sun hours	4.1	5.3	6.7	7.9	10.7	12.4	12.7	12.0	10.6	8.5	6.7	4.3
Lon: 37.22°	G (Wh/m²)	2225	3139	4278	5417	6833	7556	7556	6944	5778	4278	3028	2130
HASSAKEH	T.av (°C)	5.3	7.2	11.5	16.5	22.5	28.2	31.3	30.5	25.7	19.3	12.0	6.8
Lat: 36.50°	sun hours	4.7	5.9	6.7	7.6	9.9	12.1	12.4	11.7	10.3	8.2	6.6	4.8
Lon: 40.75°	G (Wh/m²)	2322	3222	4194	5194	6444	7333	7361	6722	5583	4111	2944	2192
MESSEL-MIYEH	T.av (°C)	4.9	6.6	10.8	15.2	20.4	25.2	26.1	27.7	24.6	18.0	11.9	6.7
Lat: 36.33°	sun hours	3.9	4.9	6.1	7.8	10.3	12.2	12.5	11.9	10.3	8.1	6.2	4.0
Lon: 37.22°	G (Wh/m²)	2158	3000	4083	5361	6694	7500	7500	6889	5694	4167	2917	2042
RAQQA	T.av (°C)	6.4	8.3	12.5	17.6	23.3	27.9	29.9	29.5	25.6	19.7	12.8	7.8
Lat: 35.95°	sun hours	4.9	5.9	7.1	8.5	10.2	12.1	12.3	11.8	10.6	8.6	7.1	5.0
Lon: 39.00°	G (Wh/m²)	2414	3278	4361	5528	6583	7361	7333	6778	5722	4250	3.11	2280
DEIR-EZZOR	T.av (°C)	6.9	9.2	13.1	18.6	24.3	29.6	32.9	31.9	27.6	21.1	13.2	8.1
Lat: 35.33°	sun hours	5.1	6.5	7.3	8.2	10.1	12.0	12.2	11.8	10.4	8.5	7.1	5.2
Lon: 35.78°	G (Wh/m²)	2469	3306	4333	5472	6556	7139	6889	6500	5556	4222	3028	2267

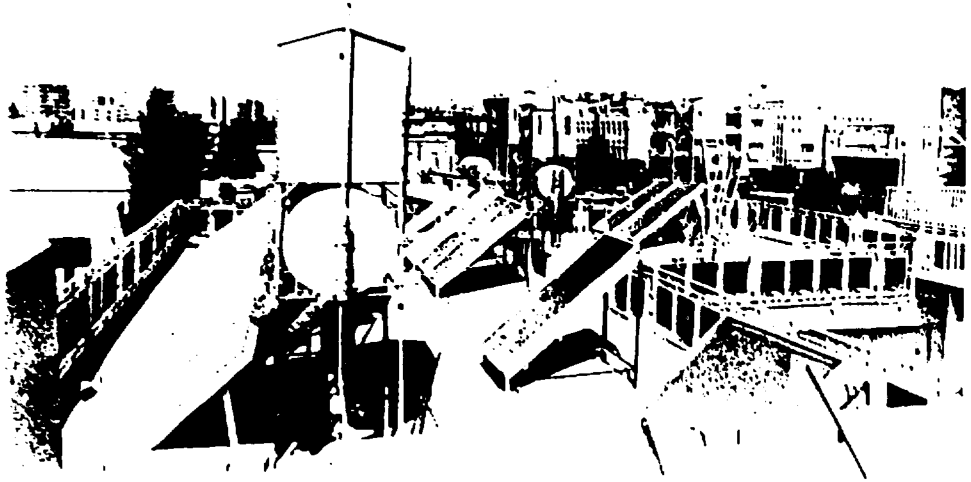
Appendix 8
ABBREVIATIONS AND ACRONYMS

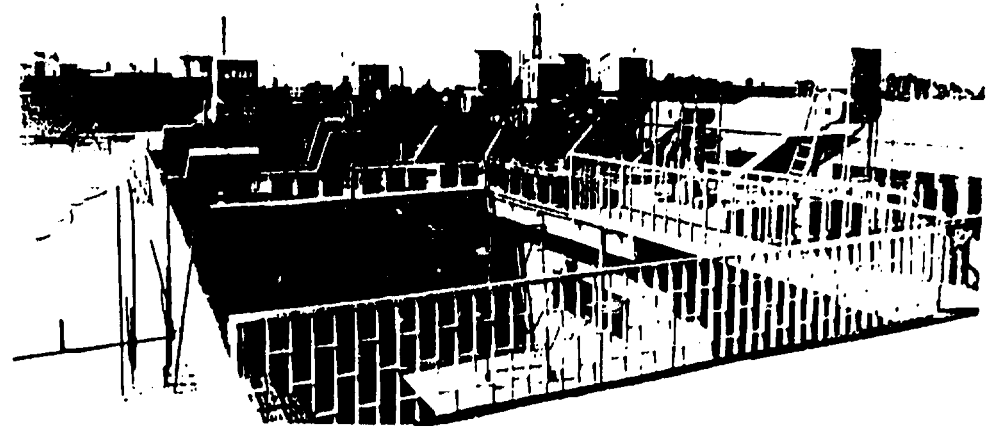
GOEI	General Organisation for Engineering Industries
HIAST	Higher Institute for Applied Sciences and Technology
ITRC	Industrial Testing and Research Centre
METALCO	Metallic Construction and Mechanical Industries Co.
MILIHOUSE	Military Housing Establishment
ORE	Office of Renewable Energy
SASMO	Syrian Standards Organisation
SSRC	Scientific Study and Research Centre

Appendix 9
SPECIFICATIONS FOR THE PROPOSED MICROCOMPUTER

IBM.XT (or compatible), with DOS
- 640 Kb RAM
- 20 MB hard disk
- one 5.25 inch floppy drive
- 8087 numeric co-processor
- Hercules graphic card

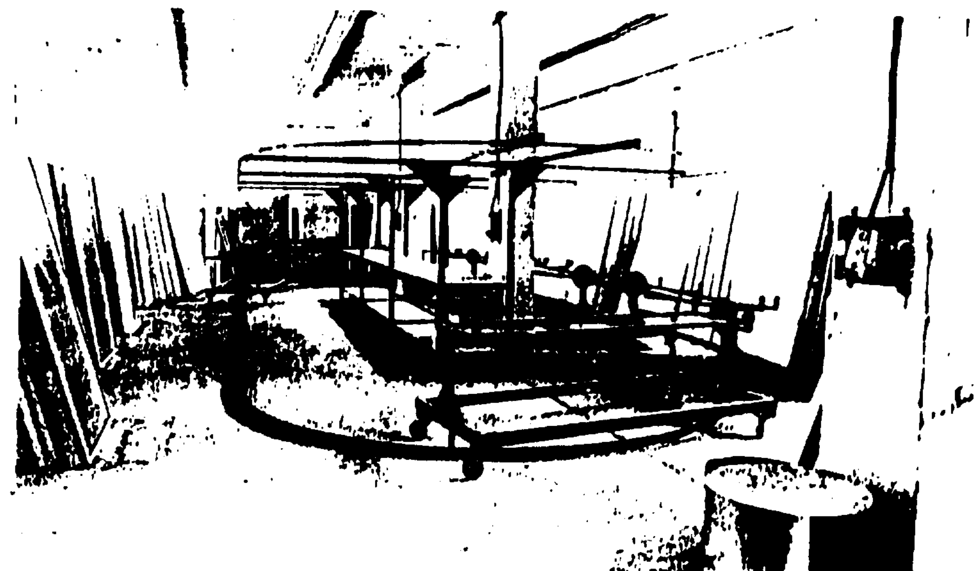
A suitable dot-matrix printer, which can be set to compressed type (16 characters/inch)





D.H.W. units, tested on the roof of the 'Solar Energy Factory'

Ready products stored in the factory yard.



The half-finished assembly line.