CREATIVE COMPONENT REPORT

INDEN 5350

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TITLE – ENERGY CONSERVATION PROJECTS FOR

GENERAL INSTRUMENT OF TAIWAN

ABSTRACT

High energy costs are providing an incentive for industry in Taiwan to conserve fuel. A major consideration is to reduce energy consumption used in heating, cooling, and illumination of the workplace.

This report consists of three different projects concerning energy conservation opportunities for one industrial plant. Project I describes the installation of a Heat Recovery Wheel in order to recover cooled exhaust air. Project II describes the installation of water coils for recovering the waste heat of furnaces to preheat hot water. Project III depicts the modification of fluorescent lighting so as to improve the illumination level and also reduce the energy consumption in lighting and in air conditioning.

It is very important to evaluate each project on its economic merits. This energy conservation opportunity analysis includes a construction or implementation cost estimate and an estimate of potential energy savings. With those two values, the most convenient economic analysis is the simple payback relation of costs and savings.

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PLANT BACKGROUND

Chi- Tu plant, a subsidiary company of General Instrument of Taiwan, is located at the northern part of Taiwan. The major products are electronic components for computer and communication systems. The plant currently employs 600 people and operates one shift and two shifts per day, 6 days a week.

The computer product division (CPD) operates two shifts (14 hours) per day while the capsule relay division (Clare) operates only one shift (8 hours) per day. The plant normally operates 292 days a year.

Two divisions are housed in this plant, a two-story building, which covers 50,000 square feet. The first floor houses the computer product division and covers approximately 20,000 sqft. The second floor houses the capsule relay division and also covers 20,000 sqft. The basement is used for utility, stock rooms, and a cafeteria. They occupy about 10,000 square feet each. Floor plans are shown in Appendix A.

Except for limited areas, the facility is air conditioned by an array of equipment all year. Air conditioning is provided both by chilled water systems and by DX (Direct eXpansion) package units. The combined capacity is approximately 400 tons of refrigeration.

Lighting is fluorescent throughout the facility. The lighting fixtures include 40 watts and 110 watts for offices and productions. The lighting fixtures for the production areas of first floor and second floor are ceiling suspended and ceiling recessed respectively.

Energy consumption at this plant for the twelve-month period March, 1986 through February, 1987 consisted of 3,923,190 kwh of electricity. This is equivalent to 13,386 MMBtu of energy. The total energy cost for the period were NT$8,912,606 (US$287,503). The details of energy consumption and cost and electricity rate structures are illustrated in Appendix B and Appendix C respectively.

PROJECT I - INSTALLATION OF HEAT WHEEL SYSTEM FOR RECOVERING THE COOLED EXHAUST AIR

Introduction

This project discusses energy saving techniques applied to an industrial facility requiring low relative humidities and 100 percent outdoor air for ventilation. Traditionally, these systems have used large capacity refrigerating and reheating equipment, often including expensive dehumidifying installations. This approach is effective from an operational standpoint, but is very costly from an energy standpoint. (Refer to page 1.3)

An energy saving alternative for this industrial facility designed to hold relative humidity to 45 percent or less at 68 F while using 100 percent outside air for ventilation will be described. This alternative uses energy recovery between outside and exhaust air streams to reduce energy consumpton for refrigerating by 50 percent.

An effective heat recovery system for using on this application is to install a heat wheel. The details of heat wheel system will be described in the later chapters. The application for this H.V.A.C. system is a mercury filling and processing facility in the Capsule Relay assembly division. This project focuses only on the room supply air conditioning system and the interfacing exhaust system.

An economic analysis is performed leading to quantified energy savings and payback period for the investment.

Data and analysis of current H.V.A.C. system

The additional data of current air conditioning system are provided as follows:

Capacity of Water Chiller (low dew point)	55 USRT *
Power input of Water Chiller	62.5 KW
Cooling Water and Chill Water Pumps	5 HP/EA.
Cooling capacity of air handling unit	594000Btuh
Supply air volume of AHU	4000 CFM
Capacity of supply air fan	5 HP
Hours of operation, one shift (8.5 hrs/day)......	2482 hrs/yr
Cost of electricity per KWH (on peak hours)	NT$2.01
Demand charge per KW	NT$141.6

* USRT - United States Refrigeration Ton (12000 BTU/RT).

Analysis of current HVAC system

The required room conditions are 68 FDB, 45% RH, enthalpy, h, of 23.5 Btu per lb dry air with a ventilation rate of one air change per minute with 100 percent outdoor air. Details of the room are not considered here.

Outdoor air conditions selected for this project were 92 FDB, 83 FWB, enthalpy, h, of 47 Btu per lb dry air, which is the design condition in summer of Taiwan. The 4000 CFM supply air is then cooled and dehumidified to 43 FDB, 42 FWB, enthalpy, h, of 16.2 Btu per lb dry air so as to meet the required ambient condition of the room. The total cooling capacity rated at 554,4000 Btu/hr which equaled to 46.2 tons

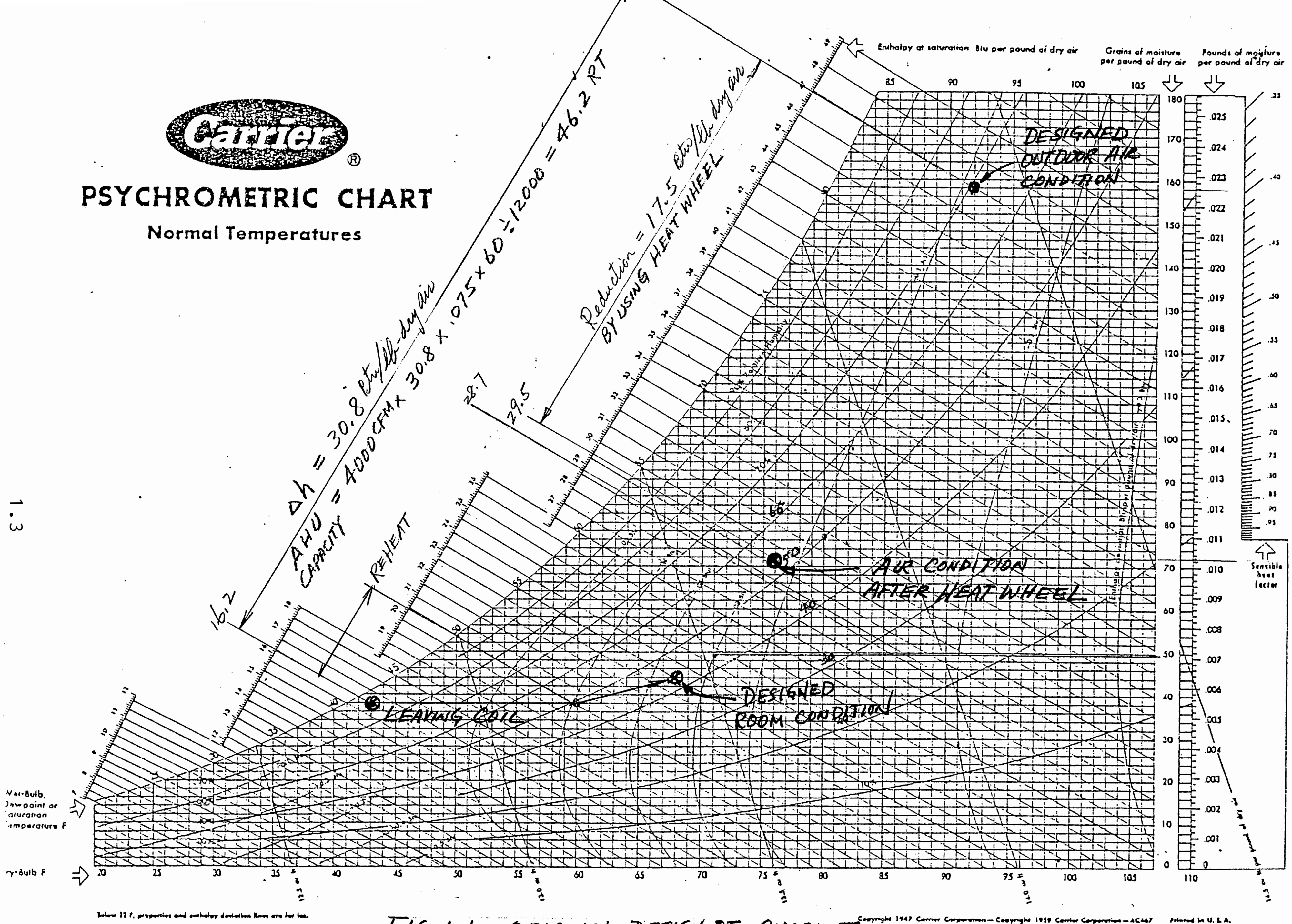


FIG 1.1 – ORIGINAL DESIGN OF CURRENT AIR CONDITIONING SYSTEM

of refrigeration. This is shown in Figure 1.1. Design conditions follow along with the necessary enthalpy and humidity ratio values taken from the Psycrometric chart.

Based on the above information, the operating cost of current HVAC system is calculated at NT$169,037 and the details are shown in Appendix D. The reductions of capacity and cost for original air conditioning system by using Heat Wheel at the first place will be shown as follows:

(i) Ambient conditions

	Temperature (F)		Humidity ratio	Enthalpy
Summer	Dry Bulb	Wet Bulb	lb./lb.	Btu/lb
Outdoor air	92	83	.0226	47.0
exhaust air	72	57.5	.007	24.8

(ii) Air volume

Outdoor air (OA) = 4,000 CFM

Exhaust air (EA) = 4,000 CFM

(iii) Air volume ratio = OA / EA = 4000 / 4000 = 1.0

(iv) From the performance chart Fig.1.2. shows the effectiveness and pressure drop desired will be .825 and .55 WG respectively.

The following calculations are applicable to the original installation of air conditioning system. Table 1.1 presents heat wheel performance.

Dry Bulb Temperature = 92 - .825 (1.0) (92 - 72) = 75.5 FDB

Enthalpy = 47 - ..825 (1.0) (47 - 24.8) = 28.7 Btu/lb dry air

The reduction in required cooling capacity

= (47 - 28.7 Btu/lb) x 4000 CFM x 60 min/hr x .075 lb/CF

= 329,400 Btu/hr

= 27 Tons of refrigeration

Table 1.2. presents a comparison between refrigeration dehumidifying process and system with and without heat wheel at design conditions. However, the practical reductions in cooling capacity should be rounded off to 25 RT (Refrigeration Ton) so to match the standard size of chiller unit. Therefore, the capital cost reductions of initial investment in retrospect would be of NT$383,250, which nearly offset the initial cost of Heat Wheel system at first place. In addition the annual dollar savings in operating cost would be NT$66,114.

Table 1.1 - Heat Wheel performance

Rated efficiency: 82.5 percent sensible and latent heat transfers for equal air flow rates in summer

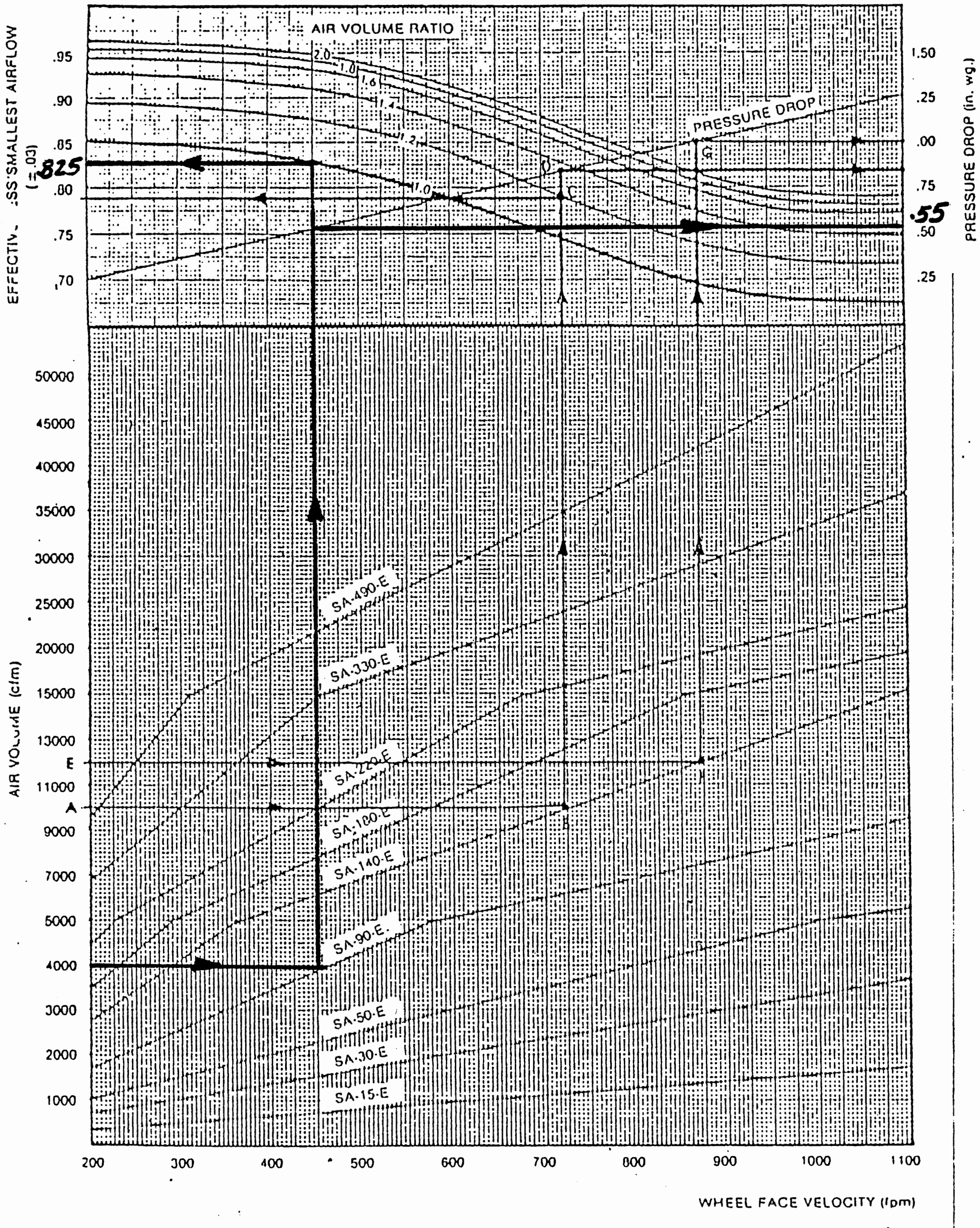
Summer performance (free cooling and dehumidifying)		(Enthalpy)
Outdoor supply air in	92 FDB / 83 FWB =	47.0 Btu/lb dry air
Room exhaust air in	72 FDB / 40 % =	24.8 "
Difference	20.0 FDB	22.2 "
Saving at 82.5 % efficiency	16.5 "	18.3 "
Supply air out	75.5 "	28.7 "
Exhaust air out	88.5 "	43.1 "

Table 1.2 - Comparison between refrigeration dehumidifying process and system with and without heat wheel at design conditions

Energy usage description	Process without heat wheel B/lb dry air	Process with heat wheel B/lb dry air	Saving Btu/lb dry air	Saving percent
Process energy consumption Total refrigeration cooling	30.8	12.5	18.3	59.4
System energy consumption Total refrigeration cooling	30.8/3=10.3	12.5/3=4.2	6.1	59.2

(COP = 3)

Fig 1.2 – PERFORMANCE CHART ENTHALPY WHEEL



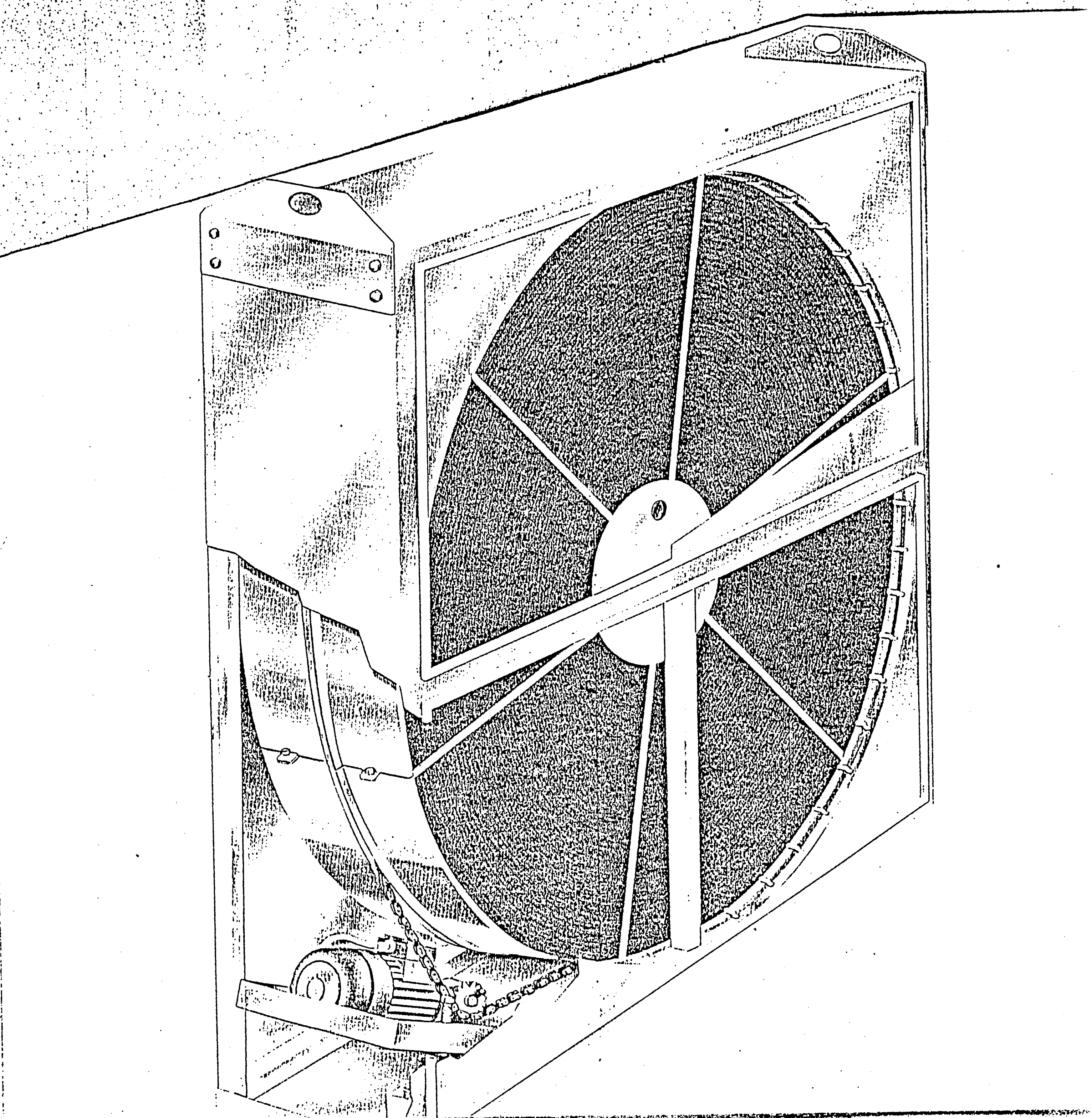
Introduction of Heat Wheel

The Heat Wheel Unit (Fig.1.3.- Enthalpy Recovery unit) is an air to air regeneration type heat exchanger, designed to substantially reduce make up air load requirements in heating and air conditioning systems. If the Heat Wheel is included in an initial system design, the reduction in equipment capacity coupled with the continuous savings in heating and air conditioning power requirements make it a very attractive investment. The Heat Wheel is equally beneficial when expanding or remodeling existing systems. In many cases, the installation of Heat Wheel can totally eliminate the need to increase the present system's heating or cooling capacity. Quite often, this reduction in equipment costs alone will more than pay for the Heat Wheel unit.

The Heat Wheel is a total air heat recovery wheel, as both sensible and latent heat are exchanged between the supply and exhaust air streams, through the Heat Wheel. Both latent and sensible heats are transferred at the same rate of effectiveness which ranges from 70% - 85% in most applications.

When the Heat Wheel is placed between two air streams in counter flow, the air stream with the lower temperature will cool the slowly rotating Heat Wheel (about 15 rpm), which in turn, heats the high temperature air stream. This is known as "sensible heat transfer". As well as exchanging sensible

Fig 1.3- HEAT WHEEL UNIT



heat" from one air stream to another, the Heat Wheel also transfers moisture between the air flows of different humidity ratios. Effective transfer of latent heat is essential since it is the largest portion of the summer cooling load. During the winter months, the moisture transfer reduces the energy required for humidification.

The heat wheel is fabricated of a metallic base to promate sensible heat transfer. It is then coated with a solid absorbent, such as silica gel, to promate moisture transfer. The wheel is designed and operated to transfer sensible and latent heat with equal effectiveness in a counterflow arrangement between supply and exhaust air stream. The features of the wheel are very desirable for both summer and winter operation. Supply air is constantly preconditioned by the room exhaust air without the addition of any new energy. uring the summer, the wheel acts as a predehumidifier and precooler. During the winter, it acts as a prehumidifier and preheater. (not appliable to this project due to mild winter weather in Taiwan)

The Heat Wheel is mounted in a heavy gauge steel casing and supported by two grease lubricated sealed ball bearings. The wheel is driven by a fractional horse power motor, with a reducing gear box, mounted in the casing on a self-adjusting motor base, and two belts driving on the rim of the wheel. The casing is equipped with two removeable air-tight side panels for easy access to the rotor and drive equipment and through which the wheel can be removed.

The casing is equipped with a Purge Sector, as standard. Flexible self-adjusting air seals made of Hypalon rubber are installed between the casing and the wheel to prevent air leakage. The standard Enthalpy Recovery Unit is designed to operate at temperature from -40 F, up to 150 F.
The performance of a rotary energy exchanger is defined by the exchanger's effectiveness and the media pressure drop. Practical face velocities for most energy recovery applications range from 500 to 800 fpm. Low face velocities give lower pressure drop, higher effectiveness, and lower operation costs, but requires larger size units with higher capital costs and more installation space. High face velocities give the reverse.

Typical pressure drop for various types of media at 500 fpm vary from 0.4" to 0.7" WG. Average effectiveness value for sensible and total heat exchangers lie in the 70 to 85% range for equal supply and exhaust air mass flow rates and normal exchanger face velocities.

Energy exchanger wheels normally operate with a minimum of required maintenance. However, the following guidelines should be followed for best performance:

1. Cleaning of the medium is needed when lint, dust, or other foreign materials build up. Cleaning method suitable for one type of medium are not necessary suitable for other types. Media treated with a liquid desiccant for total heat recovery may not be wetted; they are cleaned by vacuuming the wheel face or by using dry compressed air to blow out the passages. Metallic and nonmetallic media may be vacuumed, blown out with compressed air, hot water, or a suitable solvent. Manufacturer's cleaning instructions should be followed.
2. Drive motor and train should be maintained in accordance with manufacturer's instructions and recommendations. Particular attention must be given to speed control motors.

3. Wheels should be inspected regularly for proper belt or chain tension.
4. Refer to manufacturer's recommendations for spare and replacement parts.

Advantages and disadvantage of installing Heat Wheel

1. Reduce the cooling load of outdoor air by about 75%.
2. The effectiveness of heat transfer will reach to 70 - 85% in most applications.
3. Reduce the energy consumption dramatically on air conditioning devices.
4. Eliminate most of the sensible and latent heats from outdoor make-up air which will not only increase the capacity of air conditioning equipment, but also can increase the fresh air volume by 3 - 4 times.
5. Simple mechanism and easy maintenance.
6. Low operation costs and low noise.

The major disadvantage of installing a Heat Recovery Wheel is the high capital investment and the proximity requirement of the supply air and the exhaust air systems.

Economic Justifications

The economic justification is based on a 10 year planning horizon and the life of the heat recovery system is assumed to be 10 years. The remaining life of current HVAC system is also estimated to be 10 years. The average operating and maintenance costs of the current HVAC system and proposed heat wheel have been assumed to be uniform throughout the life of the system and are estimated to be NT$169,037 and NT$102,923 respectively. The various engineering economic techniques such as Present Worth, Annual Cost, and Incremental Benefit Cost Ratio are used for analysis. The decision arrived by using the same techniques. The Present Worth, Annual cost, and Incremental Benefit Ratio methods have been illustrated in Table 1.3.

The following economic evaluations are calculated on one shift operation basis. Fig.1.4 depicts the engineering drawing of using heat wheel in conjunction with the current HVAC system.

a. Total capital cost required for the implementation of Heat Wheel system	= NT$385,000
b. Annual operating and maintenance costs for Heat Wheel and A/C. systems	= NT$102,923
c. Annual operating cost for current A/C system	= NT$169,037
d. The reductions of operating costs in A/C system	= NT$66,114
e. The simple payback period	= 5.8 yrs

The detailed calculations are shown in Appendix G. Since the payback period is estimated to be 5.8 years, it indicated that this proposal will not be attractive unless the operating shift increases. Table 1.4. presents the economic analysis of using heat wheel for different operating hours.

Table 1.3 - Methods of economic analysis with and without heat wheel (10 years planning horizon)

	Current HVAC unit without heat wheel		Current HVAC unit with heat wheel
(1) Present worth (costs)			
Initial cost (addition)	---		NT$385,000
Operating cost			
169037/.16275	NT$1,038,630		
102923/.16275			NT$632,399
Present worth of operating cost	NT$1,038,630	>	NT$1,017,399
(2) Annual-cost			NT$385000 x CRF = NT$62,659
Operating cost	NT$169037		NT$102923
	NT$169,037	>	NT$165,582

(3) Benefit cost ratio

Incremental B/C = [(169037 - 102923)/.16275]/385000

= 406230/385000

= 1.05 > 1.0

CRF = Capital Recovery Factor = .16275 (MARR = 10%)

Not: Based on the above analysis, it indicated that the installation of heat wheel is acceptable.

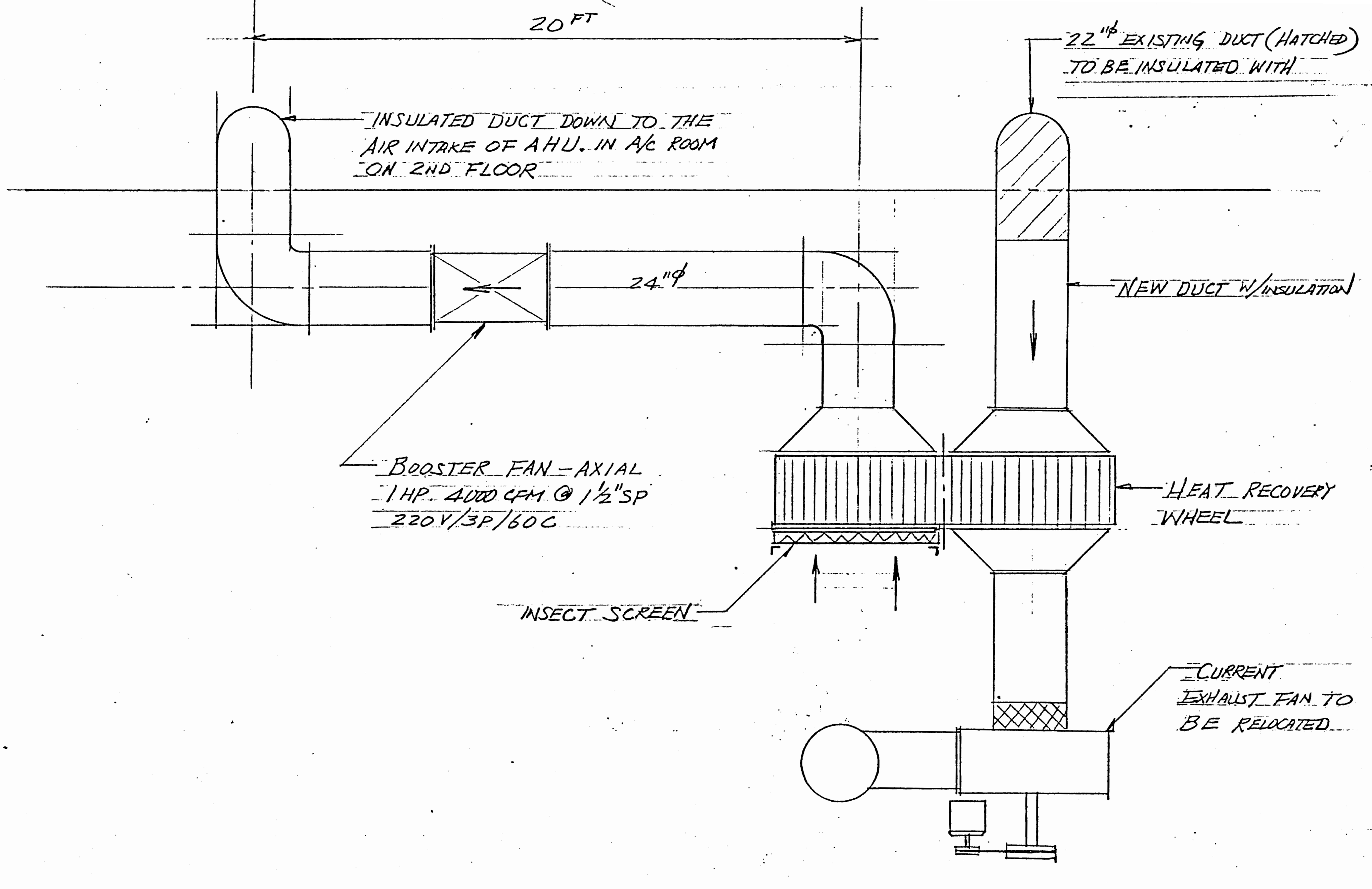


FIG 1.4 - PROPOSED INSTALLATION OF HEAT WHEEL UNIT

Table 1.4 – economic analysis of using heat wheel for different operating shifts

	one-shift 8.5 hr	two-shift 14 hr	three-shift 24 hr
ann. operating cost without heat wheel	NT$169037	NT$278414	NT$477280
operating cost with heat wheel	NT$102923	NT$169520	NT$290606
annual savings	NT$66114	NT$108894	NT$186674
implementation cost	NT$385000	NT$385000	NT$385000
payback period	5.8 yr	3.5 yr	2.1 yr

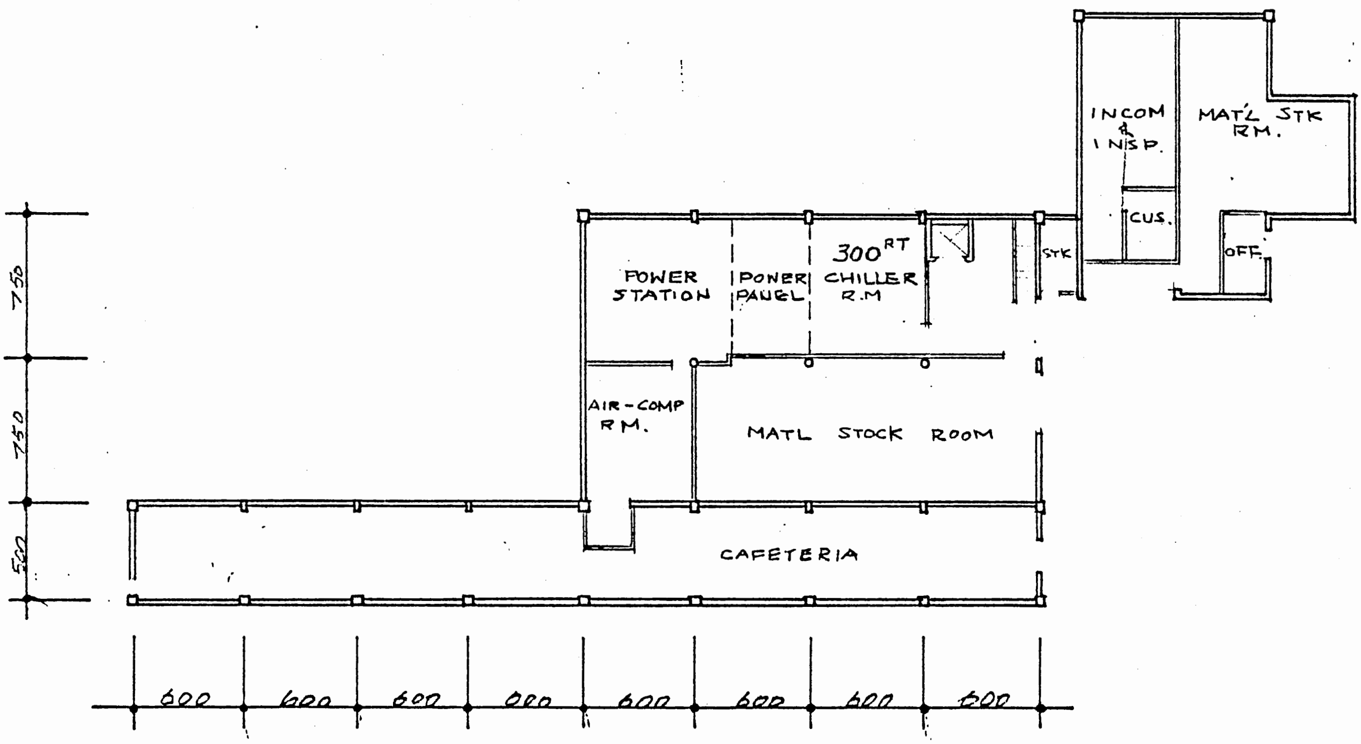
Conclusion

Energy recovery should be given careful consideration on dehumidifying systems. Total enthalpy exchanging heat wheels are excellent predehumidifying and cooling devices on 100 percent outdoor air systems. It has been indicated that using a heat wheel in conjunction with air conditioning system at the begining of installation of the facility would be justifiable. However, to install a heat wheel system may not be attractive after the air conditioning system has been installed already, unless the length of operating time of air conditioning system increases. Moreover, the current financial status and the continuity of business should be another major factors to justify the decision-making.

APPENDICES

7 6 5 4 3 2 1

Appendix A-1



A B C D E F G H I

									REV
									SHEET

REVISIONS

GENERAL INSTRUMENT — Jerrold Division, General Instrument of Taiwan Ltd.

CHECKER	APPROV.	TITLE: CHI-TU PLANT BASEMENT. S: 1/200.
DRAFTSMAN	ENGINEER	DWG. NO 6/12/86

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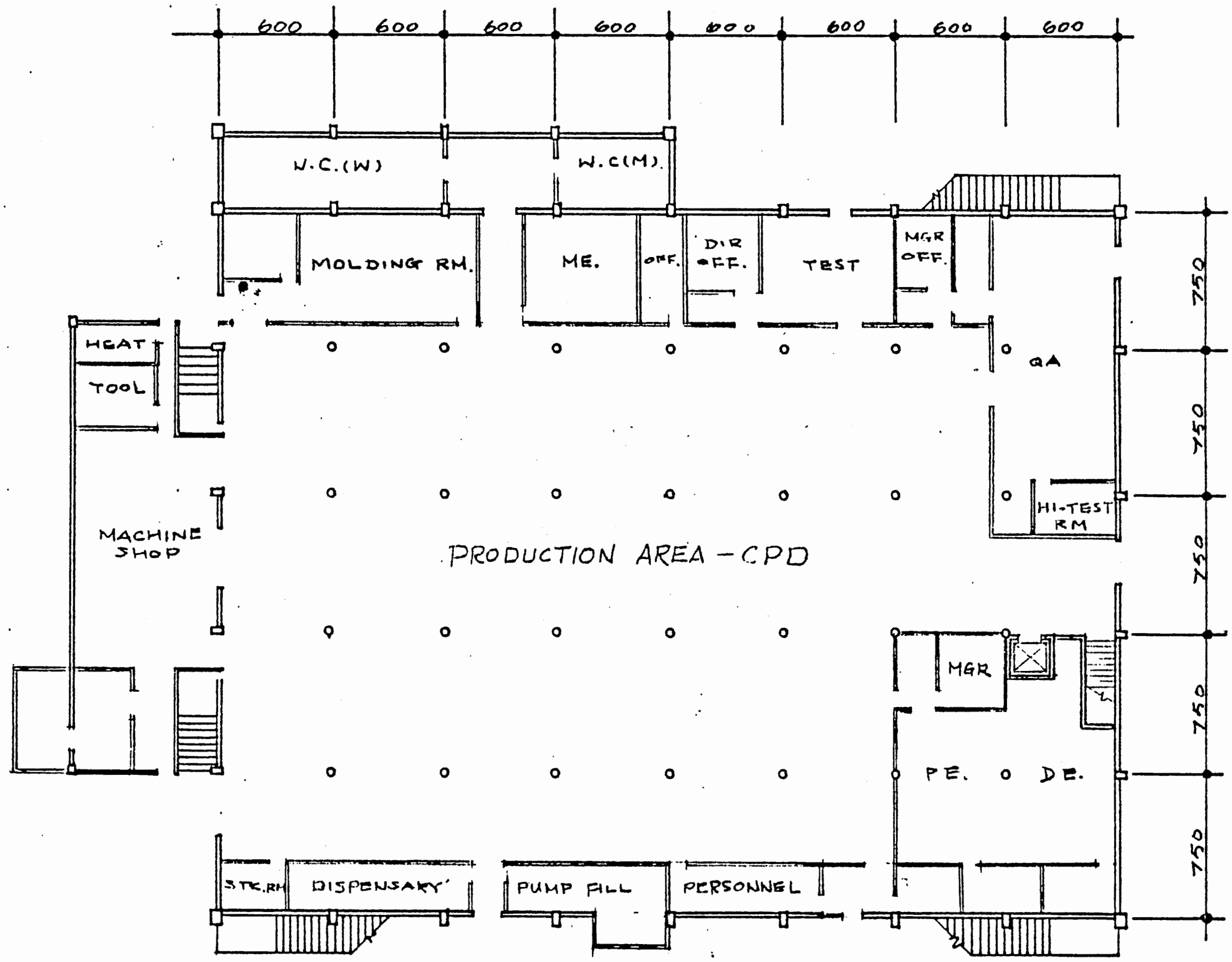
Appendix A-2



DIMENSION UNIT : CM

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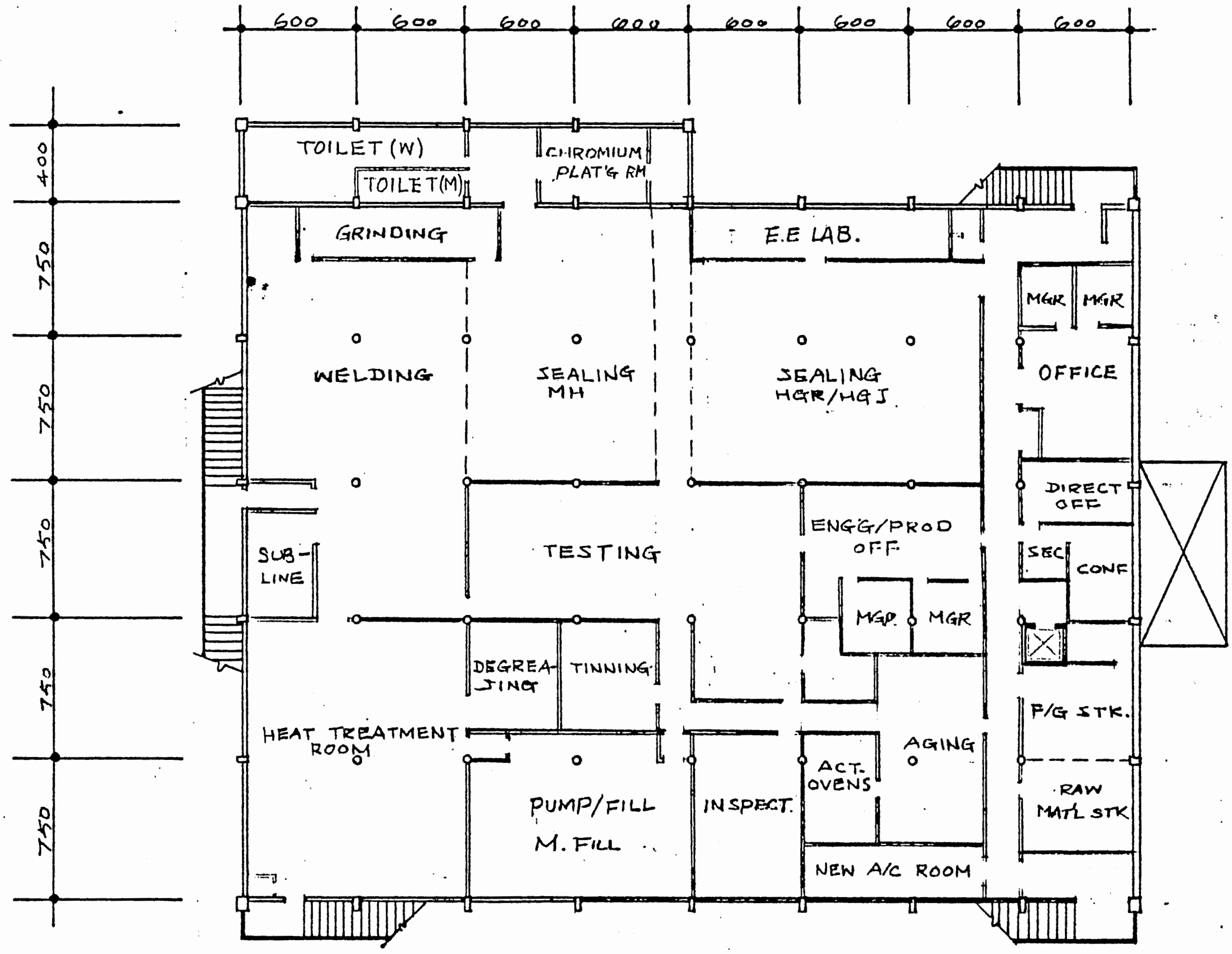
GENERAL INSTRUMENT
Jerrold Division
General Instrument
of Taiwan Ltd.

DRAFTSMAN | CHECKER | ENGINEER | APPROV.

TITLE
CHI-TU PLANT
1ST FLOOR (CPD)
S: 1/400

DWG. NO
611>184

Appendix A-3



DIMENSION UNIT: CM

CHI-TU PLANT - 2ND FLOOR (CLARE DIVISION)

SCALE = 1/400

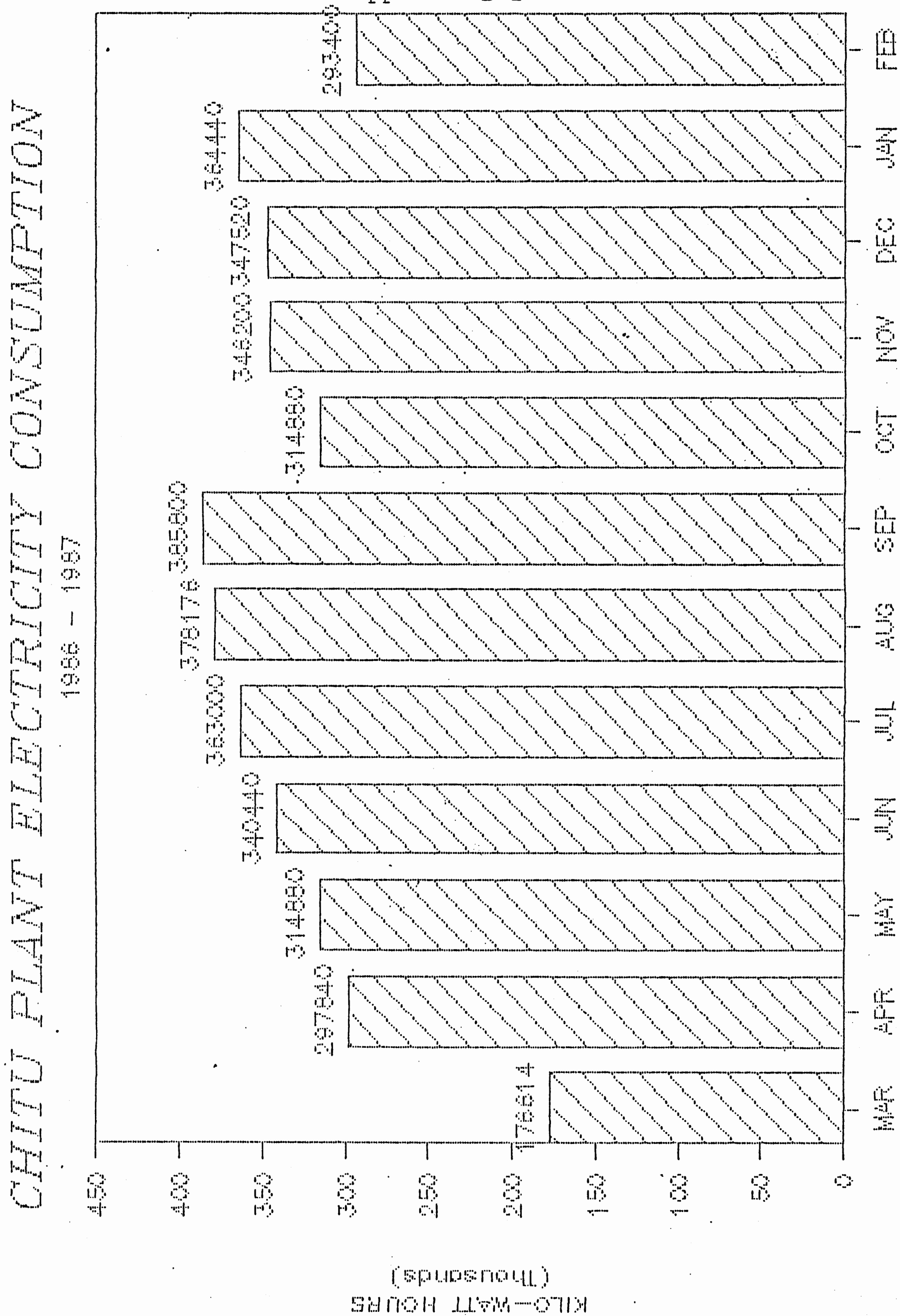
027/033/001

CHITU PLANT
ENERGY CONSUMPTION AND COST
1986--1987

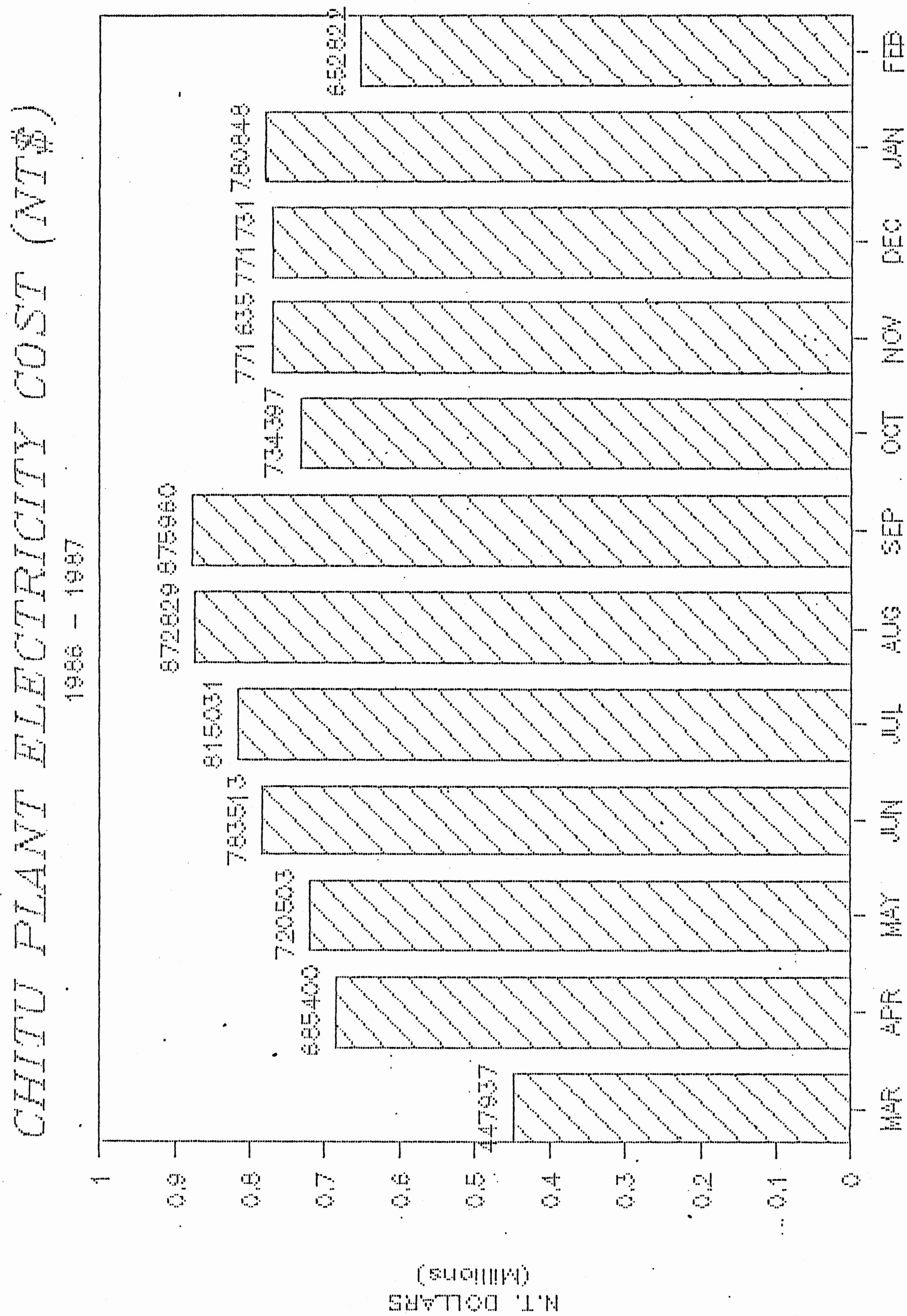
		NATURAL GAS		ELECTRICITY			TOTAL	
MONTH	MCF	MMBTU	NT$	KWH	MMBTU	NT$	MMBTU	NT$
MAR		0		176614	603	447937	603	447937
APR		0		297840	1016	685400	1016	685400
MAY		0		314880	1074	720503	1074	720503
JUN		0		340440	1162	783513	1162	783513
JUL		0		363000	1239	815031	1239	815031
AUG		0		378176	1290	872829	1290	872829
SEP		0		385800	1316	875960	1316	875960
OCT		0		314880	1074	734397	1074	734397
NOV		0		346200	1181	771635	1181	771635
DEC		0		347520	1186	771731	1186	771731
JAN		0		364440	1243	780848	1243	780848
FEB		0		293400	1001	652822	1001	652822
TOTAL	0	0	0	3923190	13386	8912606	13386	8912606

NOTES : 1MMBTU=1000000BTU
1KWH =3413BTUH
1US$ = 31NT$ as of 7/31/87

Appendix B-2


CHITU PLANT ELECTRICITY CONSUMPTION
1986 – 1987
KILO-WATT HOURS
(Thousands)
0
50
100
150
200
250
300
350
400
450
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
176614
297840
314880
340440
363000
378176
385800
314880
348200
347520
364440
293400

Appendix B-3

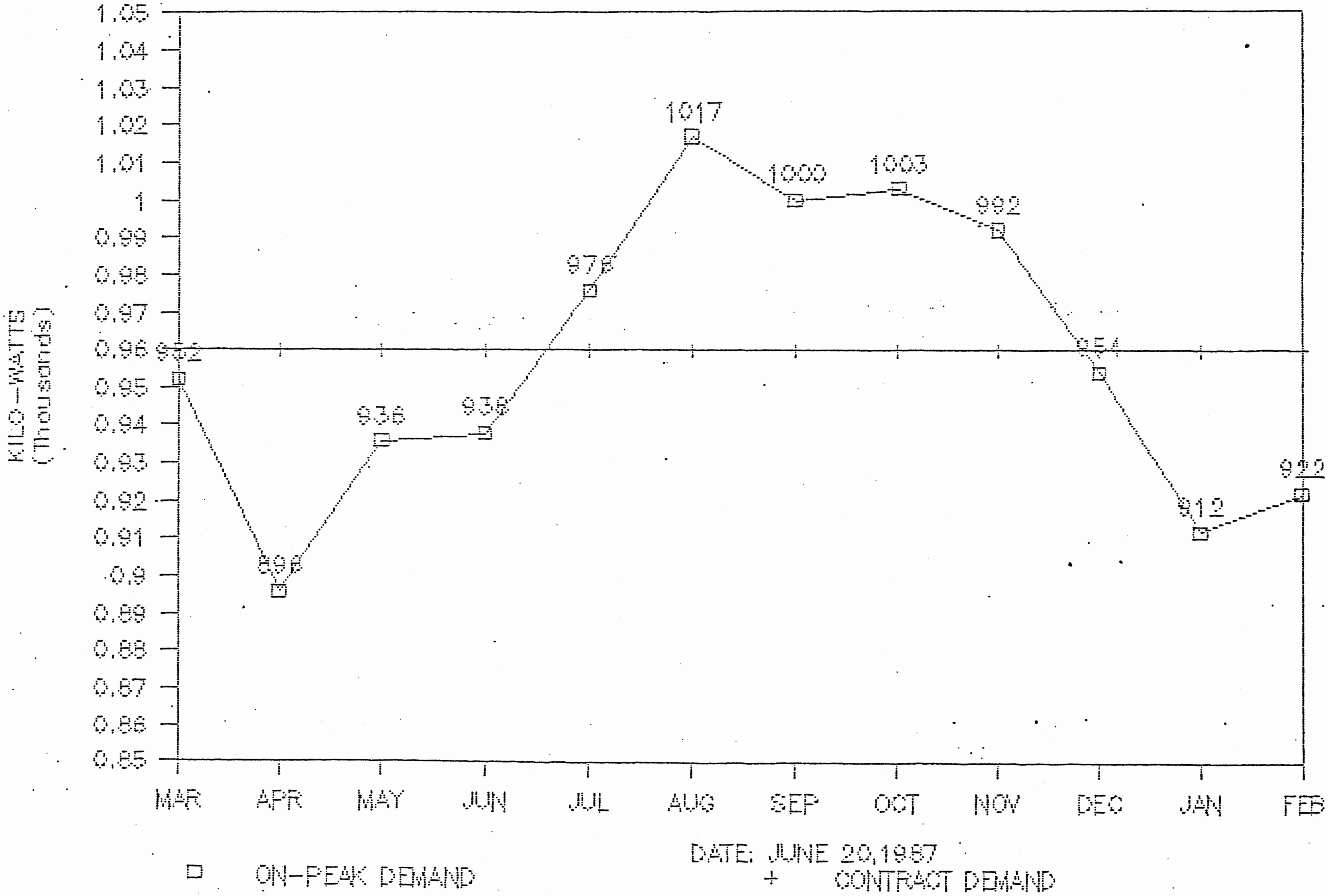


CHITU PLANT ELECTRICITY COST (NT$)
1986 - 1987
447937
685400
720503
783513
815031
872829
875960
734397
771635
771731
780848
652821
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
N.T. DOLLARS
(Millions)

Appendix B-4

CHITU ELECTRICAL DEMAND EACH MONTH

1986 – 1987



APPENDIX C

CURRENT ELECTRICITY RATE STRUCTURES

Current contract demand = 960 KW

(a). Basic charge = (contract demand kw) x NT$141.6/kw

(b). Variable charge = (on-peak consumption kwh)x NT$2.01/kwh + (off-peak consumption kwh) x NT$1.06/kwh

(c). Power factor adjustment = -0.5% x (PF - 80) x (basic charge + variable charge)

(d). Over demand penalty charge :

(i) if over is lesser than 10% of contract demand, then penalty charge = (actual on-peak demand - contract demand) x 2 x NT$141.6/kw

(ii) if over is greater than 10% of contract demand, then penalty charge = (actual on-peak demand - contract demand) x 3 x NT$141.6/kw

Total billed cost = a + b + c + d

Grand total cost = total billed cost x (1.0 + 5% tax)

Note: On-peak time starts from 0730 am to 1030 pm

Off-peak time starts from 1030 pm to 0730 am.

APPENDIX D

Energy Consumptions of Current HVAC System

for Mercury Fill Room

1) Make up air volume = 4,000 CFM

2) Ambient conditions of air leaving cooling coil = 43 FDB, 42 FWB, equivent to enthalpy of 16.2 Btu/lb of dry air.

3) Monthly energy consumption of 100% make-up air through existing air handling unit.

=(enthalpy of average outdoor condition - enthalpy of air leaving cooling coil of air handling unit) (make-up air volume)(hours of operation per day)(working day of the month)(60 min./hr)(.075 lb/cub. ft)

Mar. = (25.8 - 16.2 Btu/lb) (8.5 hrs/day) (4000 CFM) (24 days/month) (60 min/hr) (.075 lb/cub. ft)

= 35,251,200 Btuh/month

Apr. = (32.1 - 16.2) (4000) (8.5) (25) (60) (.075)

= 60,817,500 Btuh/month

May = (35.9 - 16.2) (4000) (8.5) (24) (60) (.075)

= 72,338,400 Btuh/month

June = (40.6 - 16.2) (4000) (8.5) (25) (60) (.075)

= 93,330,000 Btuh/month

July = (43.5 - 16.2) (4000) (8.5) (27) (60) (.075)

= 112,776,3000 Btuh/month

Aug. = (42.5 - 16.2) (4000) (8.5) (26) (60) (.075)

= 104,621,400 Btuh/month

Sep. = (38.6 - 16.2) (4000) (8.5) (25) (60) (.075)

= 85,680,000 Btuh/month

Oct. = (33.8 - 16.2) (4000) (8.5) (23) (60) (.075)

= 61,934,400 Btuh/month

Nov = (30.8 - 16.2) (4000) (8.5) (25) (60) (.075)

= 55,845,000 Btuh/month

Dec = (26.0 - 16.2) (4000) (8.5) (26) (60) (.075)

= 38,984,400 Btuh/month

Jan = (24.5 - 16.2) (4000) (8.5) (24) (60) (.075)

= 30,477,600 Btuh/month

Feb = (25.0 - 16.2) (4000) (8.5) (18) (60) (.075)

= 24,235,200 Btuh/month

Total energy consumption = 776,291,400 Btuh/yr

Since the performance efficiency of current chiller system equals to 1.30 kw per ton of refrigeration, the actual power consumption will be 84,098 KWH/yr which costs NT$169,037 per year for operation of current air conditioning system.

Calculations

Annual KWH consumption

= 776,291,400 Btuh/yr x 1 RT/12000 Btu x 1.30 KW/RT

= 84,098 KWH/yr

Annual operating cost

= (cost of electricity) (KWH/yr)

= (NT$2.01/kwh) (84,098 kwh/yr)

= NT$169,037/yr

APPENDIX E

Cost Estimates of Heat Wheel System

First Cost - Capital Investment

1. Heat Wheel Unit (local supplier's price)	= NT$250,000
2. Foundation and installation of heat wheel	= NT$10,000
3. Duct work with insulation	= NT$40,000
4. Booster fan for supply air stream	= NT$10,000
5. Relocation of current exhaust fan	= NT$10,000
6. Electrical work	= NT$10,000
7. Insulate current exhaust duct	= NT$20,000
8. Misc. and overhead	= NT$35,000
Total First Costs	= NT$385,000

Operating Costs

Air Conditioning System w/heat wheel	= NT$96,203/yr
Motor of heat wheel	
0.2 KW x 2482 hrs/yr x NT$2.01/kwh	= NT$998/yr
Booster fan 1.0 horse power (.746 KW)	
0.746 KW x 2482 hrs/yr x NT$2.01/kwh	= NT$3,722/yr
Maintenance cost of heat wheel	= NT$2,000/yr
Total operating and maintenance costs	= NT$102,923/yr

Currency Exchange Rate ------- 1US$ = NT$31 as of 7/31/87.

APPENDIX F

Average Outdoor Air Conditions for First Shift
Each Month in Chi-Tu, Taiwan

Month	Dry Bulb F	R.H. %	Enthalpy Btu/lb
Mar.	64	75	25.8
Apr.	72	80	32.1
May.	78	76	35.9
Jun.	83	77	40.6
Jul.	87	73	43.5
Aug.	86	73	42.5
Sep.	82	73	38.6
Oct.	76	74	33.8
Nov.	70	82	30.8
Dec.	65	73	26.0
Jan.	63	69	24.5
Feb.	62	78	25.0

Note: The above data was obtained from local weather bureau.

APPENDIX G

Supply Air Enthalpy after Heat Wheel

The conditions of supply air after the Heat Wheel are based on the following equation.

H3 = H1 − E (H1 − H2)

Where

H1 = average outdoor air enthalpy in each month

H2 = current exhaust air enthalpy = 24.5 Btu/lb dry air

H3 = enthalpy of supply air after Heat Wheel

E = Effectiveness of performance of Heat Wheel

= .825 (obtained from performance chart)

Results of H3 in each month are as follows:

Mar. = 25.8 − .825 (25.8 − 24.5) = 24.7 Btu/lb.

Apr. = 32.1 − .825 (32.1 − 24.5) = 25.8

May. = 35.9 − .825 (35.9 − 24.5) = 26.5

Jun. = 40.6 − .825 (40.6 − 24.5) = 27.3

Jul. = 43.5 − .825 (43.5 − 24.5) = 27.8

Aug. = 42.5 − .825 (42.5 − 24.5) = 27.7

Sep. = 38.6 − .825 (38.6 − 24.5) = 27.0

Oct. = 33.8 − .825 (33.8 − 24.5) = 26.1

Nov. = 30.8 − .825 (30.8 − 24.5) = 25.6

Dec. = 26.0 − .825 (26.0 − 24.5) = 24.8

Jan. = 24.5 − .825 (24.5 − 24.5) = 24.5

Feb. = 25.0 − .825 (25.0 − 24.5) = 24.6

APPENDIX H

Calculations of Energy Consumption and Costs by Using Heat Wheel System

Energy consumption in each month = (air enthalpy after heat wheel - designed air enthalpy leaving cooling coil) (working days/mon) (supply air volume)(operating hrs/day)(air density) (60 min/h)

Mar. = (24.7 - 16.2)(24)(4000)(8.5)(.075)(60) = 31,212,000

Apr. = (25.8 - 16.2)(25) (153000) = 36,720,000

May. = (26.5 - 16.2)(24) (153000) = 37,821,600

Jun. = (27.3 - 16.2)(25) (153000) = 42,457,500

Jul. = (27.8 - 16.2)(27) (153000) = 47,919,600

Aug. = (27.7 - 16.2)(26) (153000) = 45,747,000

Sep. = (27.0 - 16.2)(25) (153000) = 41,310,000

Oct. = (26.1 - 16.2)(23) (153000) = 34,838,100

Nov. = (25.6 - 16.2)(25) (153000) = 35,955,000

Dec. = (24.8 - 16.2)(26) (153000) = 34,210,800

Jan. = (24.5 - 16.2)(24) (153000) = 30,477,600

Feb. = (24.6 - 16.2)(18) (153000) = 23,133,600

Annual total energy consumption = 441,802,800 Btu/yr

KWH consumption = 441802800 Btu/yr x 1/12000 Btu x 1.3 KW/RT

= 47,862 KWH/yr

Energy cost = NT$2.01 x 47862

= NT$96,203

Total operating and maintenance costs (Appendix E)

= NT$102,923/yr

Annual dollar savings by using heat wheel

= 169037 - 102923

= NT$66,114/yr

Implementation cost (refer to Appendix E)

= NT$385,000

Simple payback period

= 385000/66114

= 5.8 years

PROJECT II - RECOVER WASTE HEAT TO HEAT WATER

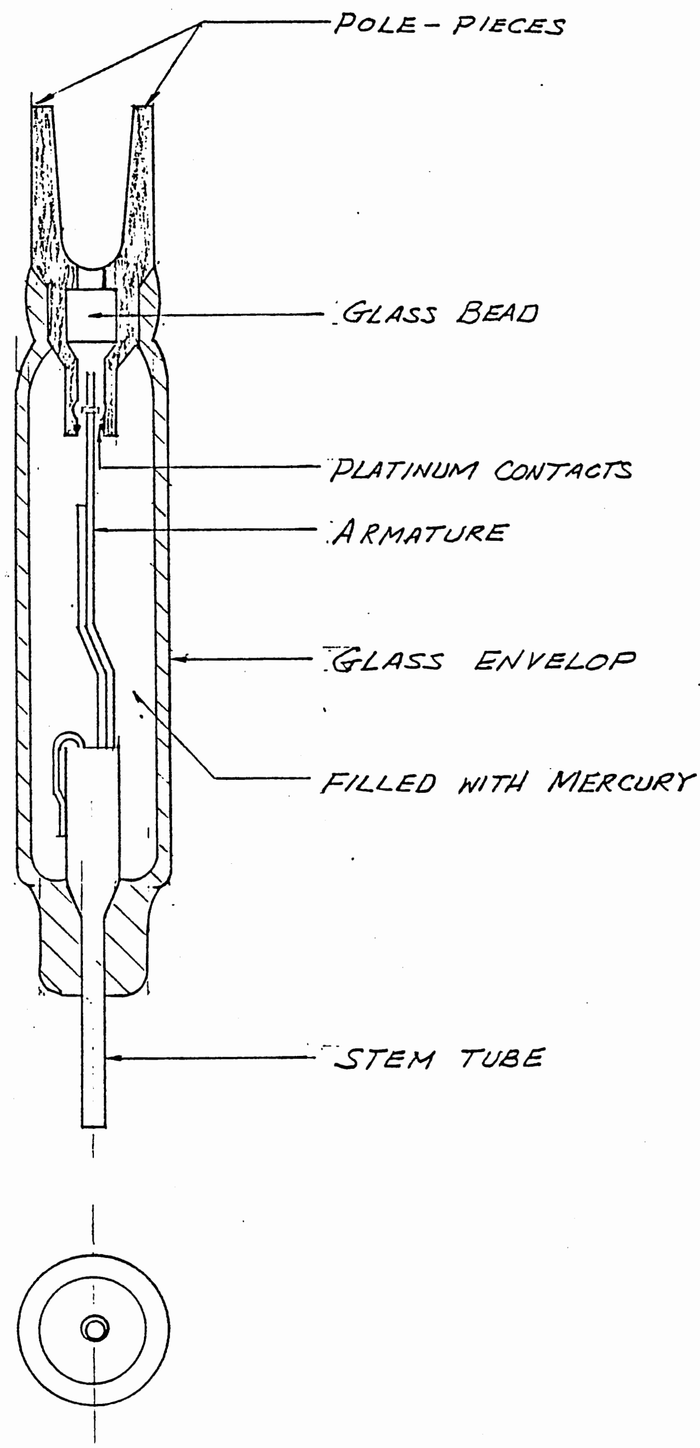


Fig 2.1 — HGR CAPSULE

James

Introduction

Waste heat recovery can be accomplished by insertion of heat exchange elements into process air or water streams, or by the flow of process water through heat recovery equipment. Heat recovered from this separate equipment is frequently used to preheat cold water entering the service water heater. Many processes are used in the commerical and industrial sector from which waste heat is available. This project will consider only the heat available from furnaces.

There are two sets of belt furnaces located in the heat treatment room. (refer to Fig. 2.2) One is a glass annealing furnace, and the other one is a metal annealing furnace. The major function of the glass annealing furnace is to eliminate the internal stress of glass envelop of HGR (Hydrogen Glassed Relay) capsules (refer to Fig.2.1), and the function of metal annealing furnace is to remove the oxidation layer of metal stems of products. These two furnaces are filled with hydrogen where the combustion take place (Hydrogen is a self-combustiable gas). After the process of combustion, the waste energy then burns off from the two vertical burners which are located at both end of each furnaces.

In order to conserve energy and to save bucks, it has been consider to install a heat recovery system which captures some of heat that is being thrown away and use it to heat water so that the company does not have to buy raw energy to do so. The hot water is currently used for parts cleaning process in the Tinning and Degreasing rooms.

An economic analysis is performed leading to quantified energy savings and payback period for investment.

Data and analysis of present waste heat

Fig. 2.2 presents a conventional exhaust system in the heat treatment room which operates for removing the waste heat to the outdoor atmosphere. The exhaust duct is insulated with 1 inch thick fiber glass, and exhaust fan is located at the corner of the room. Because of the improper installation of local hoods over the burn-offs, and the lengthy duct runs. This installation causes a lot of heat to dissipate into the room before going outdoors. It also dramatically increases the air conditioning load of the room.

In order to improve the current situation, an effort has been taken to obtain the following information from the support of production engineer on the site. (Details are given in Appendix A)

No. of furnaces	= 2
Hydrogen consumption of each furnace	= 280 scfh
High heating value of H2	= 61095 Btu/lb
Density of H2 at 80 F	= .00511 lb/cf
Total input energy of two furnaces	= 174830 Btu/hr

Heat losses from surfaces and cooling water	= 74830 Btu/hr
Current operating hours/day	= 5 hrs
current operating days/year	= 200 days

From the above information, the total waste heat rejected from burn-offs are calculated to be 100,000 Btu/hr, it is equivalent to 100 MMBtu/yr of energy. This amount of heat will then be removed through the heat recovery unit by an exhaust fan rated at 1200 cu.ft. per minute. The waste heat air temperature before entering the heat recovery unit is calculated at 167 degree F.

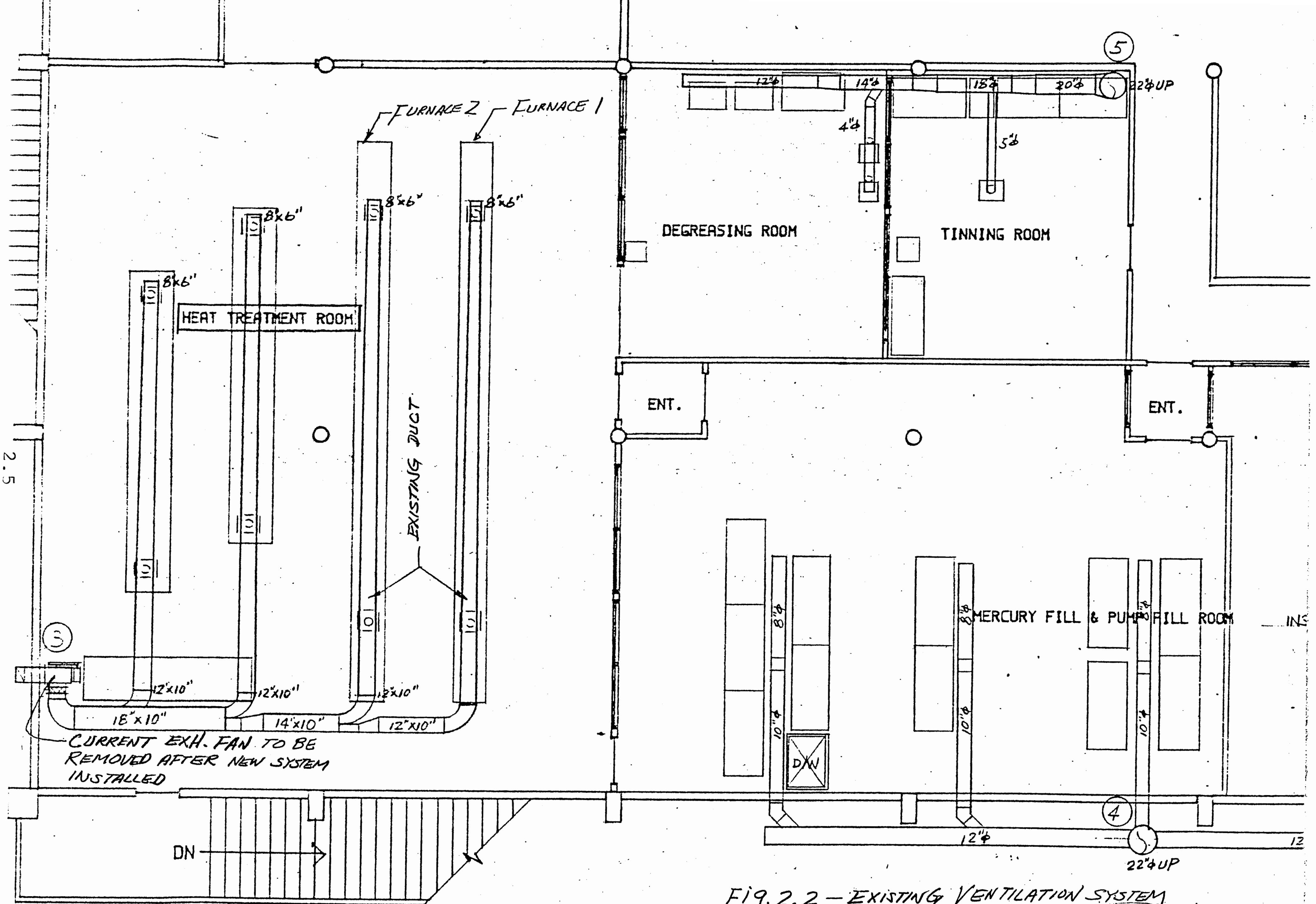


Fig. 2.2 — EXISTING VENTILATION SYSTEM OF HEAT TREATMENT ROOM

Analysis of current hot water system

The current hot water system is supplied by two electrical water heaters, which consist of a combination of a heating element and control assembly for the close control of leaving hot water temperature. The hot water is used for parts cleaning in the Degreasing and Tinning rooms. The cleaning process of Degreasing uses hot water at a more or less steady rate throughout the day, while the Tinning room uses the hot water on batch basis. From actual measurement, the current flow rates of hot water for Degreasing and Tinning operations are 50 GPH and 70 GPH respectively. The service temperatures are required at 160 F (70 C) for both operations, and the existing operating hours of cleaning processes are 2336 hours (8 hrs x 292) per year. The holding volumes of hot water tanks for Degreasing and Tinning operations are 100 gallons and 80 gallons respectively.

Because of the process requirement, the make-up water is de-ionized which is currently supplied from an in-house water treatment station. Based on the above information, it has been calculated that the annual energy consumption of hot water would be of 187 MMBtu/yr. This is equivalent to 68,488 kwh/yr of electricity. The annual operating cost is estimated at NT$158,051/yr. The above detailed calculations are shown in Appendix B.

Waste heat recovery system

Fig.2.3a and 2.3b present the engineering drawings of the waste heat recovery system which consists of a new ventilation system with a heat exchanger unit. The raw make-up water will then go through the heat exchanger to absorb the heat from the waste heat air stream. The preheated water will be pumped into the existing two water heaters while the hot water in use, or recirculated the preheated water into a intermediate storage tank if the hot water is not in use. The new ventilation system has to be well insulated and the local hoods of burn-offs should be entirely encompassed to minimize the dissipation of heat from the new ventilation system.

The real benefits of heat recovery is to capture the waste heat from furnaces which can provide a water heating energy saving of 25 to 100 percent. The actual saving achieved depends on the match and the length of time between hot water use and furnaces use. In this facility, the proposed heat recovery system could provide about 53% of the hot water usage year-round.

The heat recovery unit is similar to a water coil unit. This unit utilizes extended surface, finned-tube water coils placed in the exhaust airstream to recover the waste heat and transfer the heat to the existing water heaters or store it in a storage tank. The proposed system diagram of heat recovery water heating system is illustrated in Fig.2.4. This

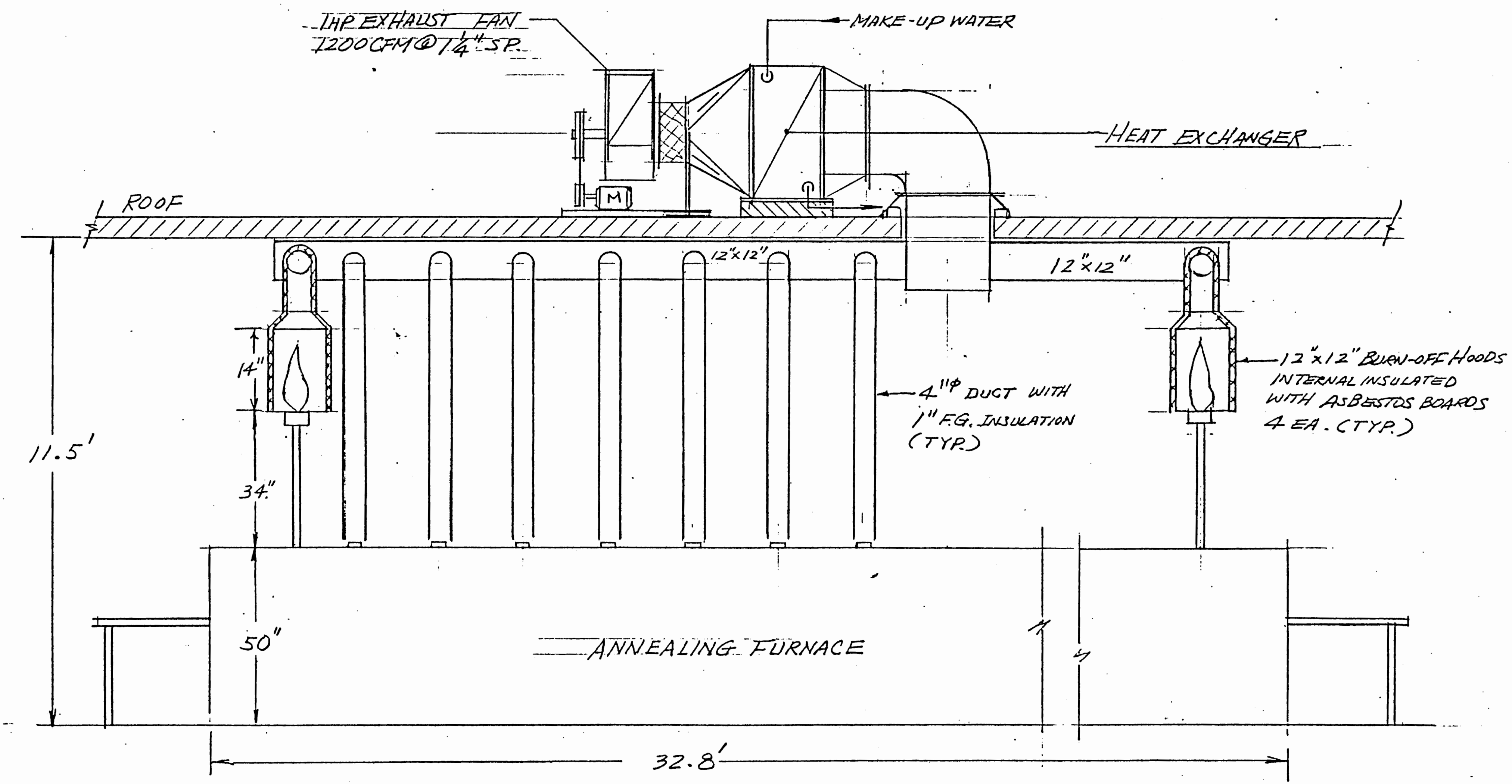


FIG. 2.3a DETAILS OF HEAT RECOVERY SYSTEM S: 1/400 DWN BY: James

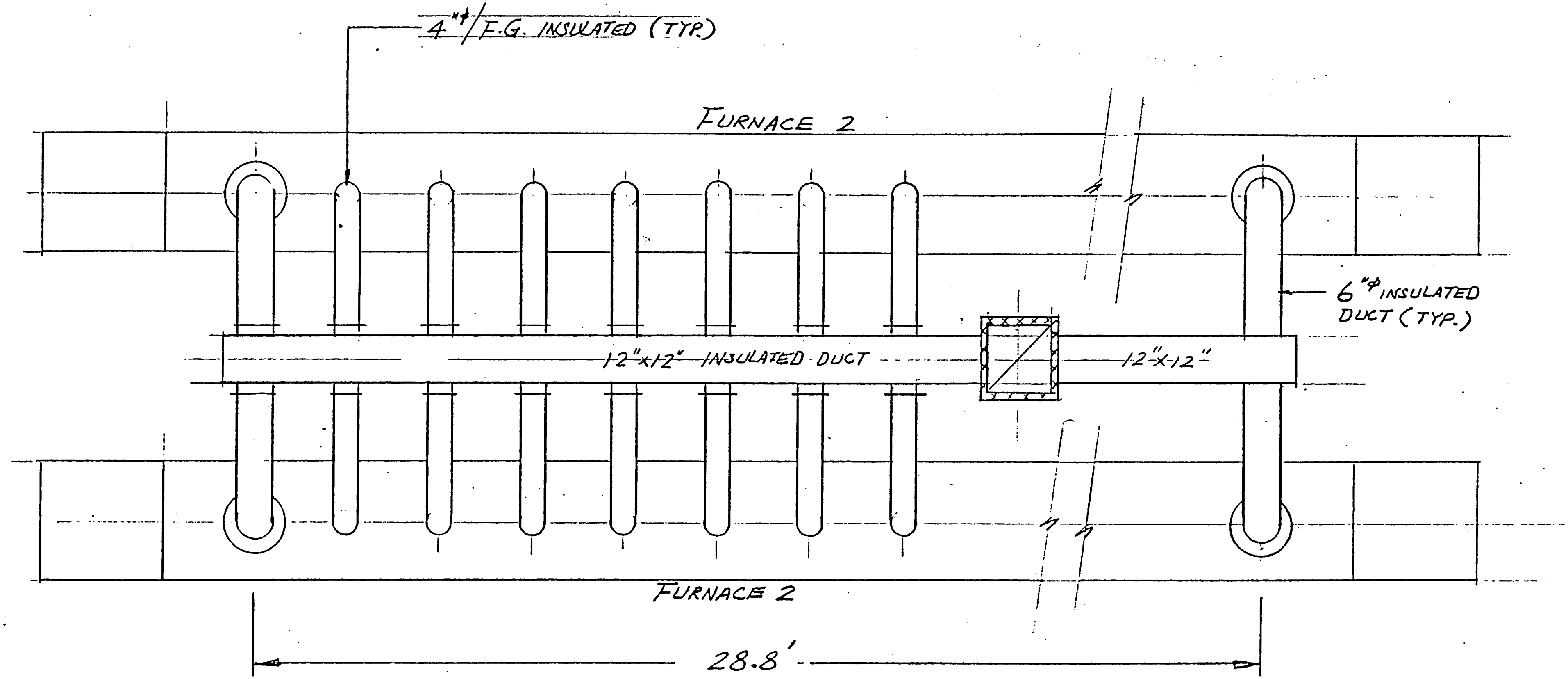


FIG. 2.3b DUCT WORK OF WASTE HEAT RECOVERY
TOP VIEW S: 1/400

DWN BY: James

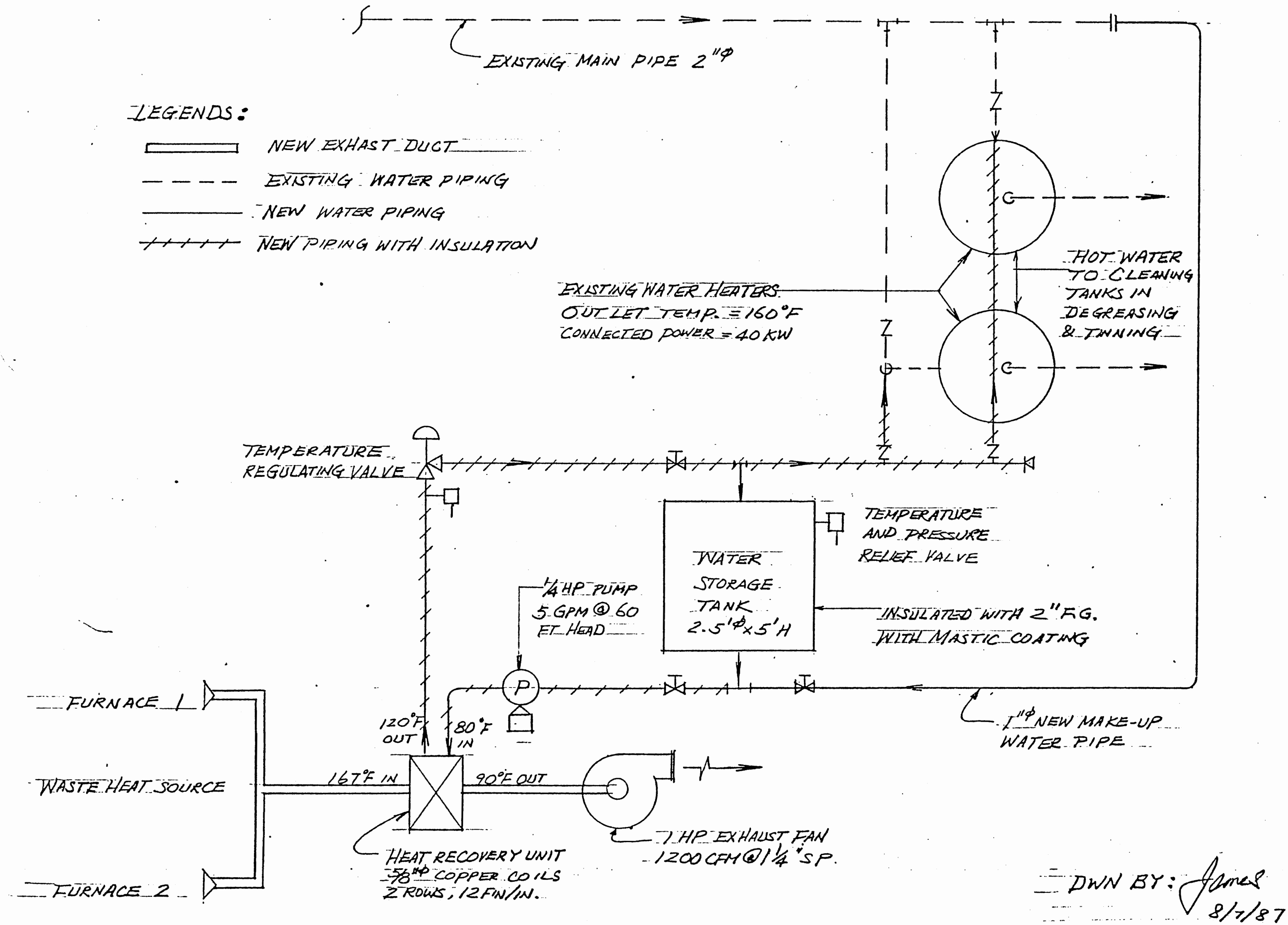


FIG 2.4 — HEAT RECOVERY WATER HEATING SYSTEM

system operates generally for sensible heat recovery.

The heat recovery unit, which is generally available as a cooling coil, should be rated at least 100,000 Btu/hr of water flow rate at 5 gpm. The coil contractor should provide the detail and cost of this unit. The circulating pump for this system should be low-flow, low heat machine, and the capacity of pump will be of 1/4 hp, 5 gpm at 60 ft head. The volume of preheated water storage tank is 20 cub. ft (150 gallons) and the tank to be insulated with 2-in. fiberglass with mastic coating. The piping shall be of No.40 stainless steel so to eliminate the contamination of de-ionized water for hot water usages.

The gate valves and check valves are installed to prevent the back flow of hot water and to facilitate the changeover during the maintenance and breakdown of heat recovery unit. Besides, insulating all pipes in the system is important to maximize savings and protect personnel from burns.

Economic analysis

The following economic analysis is based on current operating hours of this facility.

a.	annual operating cost of existing hot water system	= NT$158,051
b.	annual dollar savings from recovered waste heat of furnaces	= NT$49,127
c.	implementation cost	= NT$176,000
d.	payback period	= 3.6 yrs

The above calculations are shown in Appendix C, in which the annual dollar savings did not include the potential energy reduction in air conditioning load of the room. Therefore the actual payback period should be less than 3.6 years.

Conclusion

The utilization of waste heat recovery to preheat the hot water is being used widely in the industrial plant to conserve energy recently. The favorable savings will be obtained from increases of the operating hours between furnaces and the hot water usages.

Waste heat recovery from furnaces can be achieved by using waste-heat boiler in which the hot exit air from furnaces will be captured to generate steam. In addition, the heat recovery can be associated with other type of building mechanical equipment system applications, such as air-conditioning or refrigeration compressors.

APPENDICES

APPENDIX A

Calculations of Current Waste Heat of Furnaces

Hydrogen consumption of each furnace = 280 SCFH

Density of Hydrogen at 80 F = .00511 lb/cub. ft

High heating value of hydrogen = 61095 Btu/lb

Total hydrogen consumption = 2 x 280 cfh x .00511 lb/cf

= 2.8616 lb/hr

Total input energy = 61095 Btu/lb x 2.8616 lb/hr

= 174,830 Btu/hr

Flow rate of cooling water = 2.5 gpm/furnace

Temperature difference between inlet and outlet = 20 F

Total heat removed from cooling water

= 500 x 2.5 gpm x 2 x 20 F

= 50,000 Btu/hr

Total areas of insulated furnaces = 325 SQFT

Surface temperature Ts = 150 F

Ambient temperature Ta = 85 F

Surface resistance Rs = .85

Total surface heat loss of furnaces

= (150 - 85 / .85) x 325 SQFT

= (76.4 Btu/hr-SQFT) x 325 SQFT

= 24,830 Btu/hr

Total heat rejected from burn-offs = 100,000 Btu/hr

= potential heat to be recovered (approximately)

Flow rate of new exhaust fan = 1200 CFM

The face area of heat recovery unit = 4 SQFT

Face volicity of heat recovery unit = 300 FPM

APPENDIX B

Energy Consumption of Current Hot Water

Calculations :

Hot water usage in Degreasing room - Constant flow

= 50 GPH = 0.83 gpm

Hot water flow rate in Tinning room - Batch process = 2 gpm

and total hot water usage time per hour = 35 min/hr

Hot water usage in Tinning = 70 GPH

Total hot water usage = 120 GPH = 2 GPM

Efficiency of existing water heaters = 80%

T1 = make-up water temperature at 80 F

T2 = Required hot water temperature at 160 F

Power demand load (constant flow only)

= .83 x 8.33 x 60 x (160 - 80) x 1/3413 x 1/0.8

= 12 KW

Btu consumption in hot water

= 2 gpm x 8.3 lb/gal x 60 min/hr x 1 Btu/lb F x (T1 - T2)

= 2 x 500 x (80)

= 80,000 Btu/hr

Energy consumption per year

= 80000 Btu/hr x 8 hr/day x 292 days/yr

= 187 MMBtu/yr

KWH consumption per year

= (187 MMBtu/yr) (1 kwh/3413 Btu) (1/eff. of water heater)

= 187000000 x 1/3413 x 1/0.8

= 68,488 KWH/yr

Annual operating cost

= (68488 kwh/yr)(NT$2.01/kwh) + (12 kw)(NT$141.6)(12 mos/yr)

= NT$158,051/yr

APPENDIX C

Calculations of Waste Heat Recovery System

Air volume of waste heat at 167 F = 1200 CFM

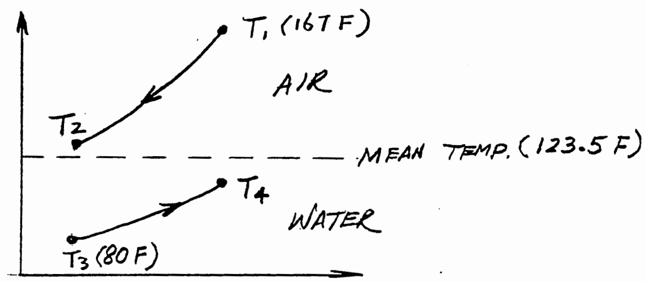
Designed make-up water flow rate = 5 gpm = 300 gph

T1 = Temp. of air entering the heat recovery coil = 167 F

T2 = Temp. of air leaving the coil = 120 F

T3 = Temp. of make-up water entering the coil = 80 F

T4 = Temp. of heated water leaving the coil



Q1 = Rejected heat from waste heat air stream

Q2 = Heat to be recovered through water = Q1

Q1 = 1200 cfm x density of air x sp.heat of air x 60 m/hr x

(T1 - T2)

= 1200 x .075 x .24 x 60 x (167 - 120)

= 60912 Btu/hr

To find T4 -

Q2 = 5 gpm x 8.33 lb/g x 60 m/hr x 1 Btu/lb-F x (T4 - 80)

= Q2 = 60912

T4 = 104 F

Total annual energy recovered = 60912 x 5 x 200 = 61 MMBtu/yr

Power demand savings for constant water flow only

= .83 gpm x 9.33 x 60 x 1 x (104 - 80)

= 3 KW

Equivalent KWH savings in water heater

= (energy recovered) x (conv. factor) x (1/heater eff.)

= 60912 x 1/3413 x 1/.8

= 22341 kwh/yr

Dollar savings in hot water

= (NT$2.01/kwh x 22341 kwh/yr) + (NT$141.6 x 3 kw x 12 m/yr)

= NT$50,003/yr

Net annual dollar savings

= 50003 - (1/4 HP x .746 x 8 x 292 x 2.01)

= NT$49,127

Implementation cost

= (heat recovery unit) + (vent duct work and hoods) +

(installation of fan and heat recovery unit) +

(electrical work) + (preheat water storage tank w/controls)

+ (piping, fittings insulation and installation labor) +

(misc. and overhead)

= 20000 + 80000 + 10000 + 10000 + 30000 + 10000 + 16000

= NT$176,000

Simple payback period

= 176000/49127

= 3.6 years

Note: Because of the heat losses from the storage tank is minimal, it was not included in the above calculations.

PROJECT III - MODIFYING FLUORESCENT LIGHTING SYSTEM

Introduction

The 2nd floor production area illumination is provided by a uniform layout of 8 foot ceiling -recessed fluorescent fixtures. This type of lighting fixture consumes approximately 220 watts per fixture when equipped with standard 110-watt lamps. The current light fixtures were installed seven years ago. The main reason of using general lighting system was due to the consideration of uniform distribution of illumination for the entire areas.

A task lighting (local lighting) system has been considered to replace the existing general lighting system. The area to be covered with new lighting system at this time will be Sealing area on the 2nd floor. The installation of task lights includes 4 foot light fixture (38-watt EE lamp) to be mounted above the workbench. More detailed information concerning this lighting system has been included in the following chapters.

Analysis of existing lighting system

Fig.3.1a and Fig.3.1b show the section view of current workbench and general lighting layout respectively. The other related data of current lighting system is provided as follows:

a. No. of existing light fixtures	=	72 sets
b. No. of lamps 8-foot, 110 watts	=	144 lamps
c. Illumination level on workplanes	=	30 - 50 FC
d. Lamp output at 70% of rated life	=	7500 lumens
e. Average life of lamp	=	10,000 hrs
f. Operating hours per year (1st shift)	=	2,482 hrs
g. Cost of electricity per kwh	=	NT$2.01/kwh
h. Demand charge	=	NT$141.6/kw
i. Cost of lamps 8-foot	=	NT$200/lamp
j. Cost of ballast, 8-foot light fixture	=	NT$700/EA.
k. Average life of ballasts (10 years)	=	30,000 hrs

Based on the above information, it has been calculated that the total energy consumption will be of 56,830 kwh/yr. The annual operating cost would be approximately NT$172,023. The detailed calculations are shown in the Appendix A.

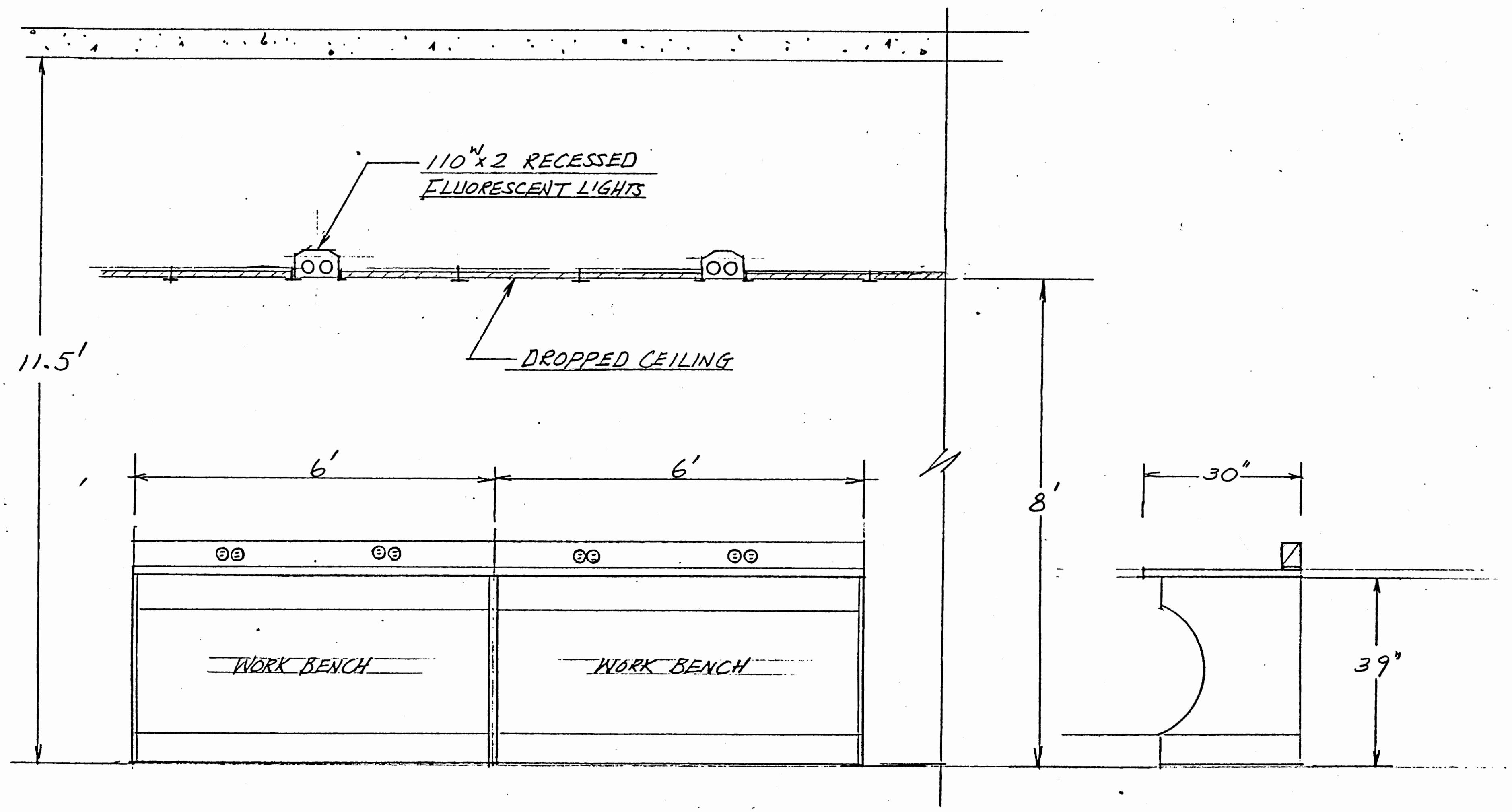


FIG 3.1a - CURRENT WORK STATIONS/LIGHTS S: 1/30

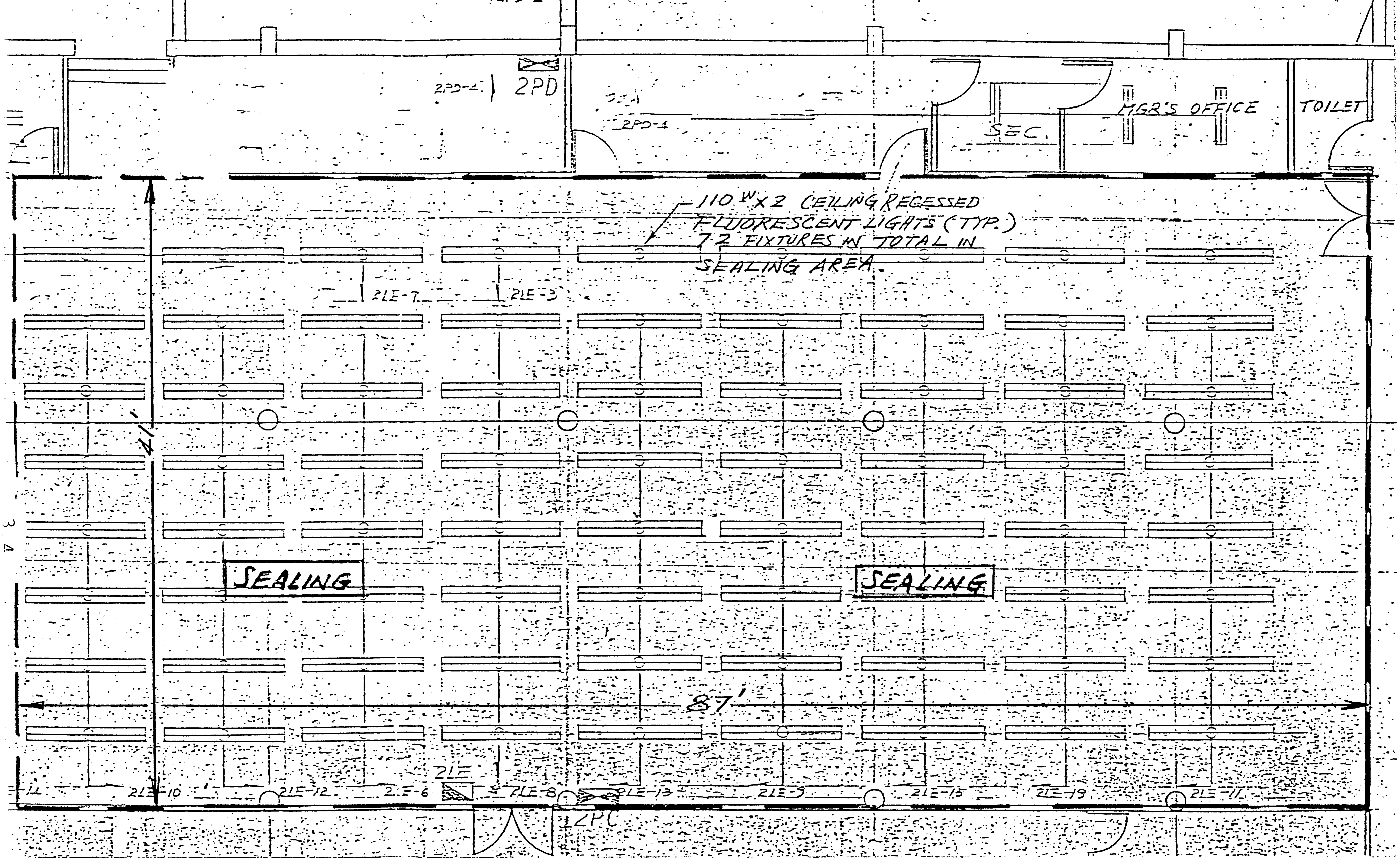


Fig3.1b - Current general lighting layout

Analysis of installing task-lighting system

Fig.3.2a presents the task-lighting fixtures which is mounted three feet above the workbench and supported by 1" dia. pipe brackets and Fig.3.2b presents the proposed task lighting layout. In such situation, the illumination is proportional to the candlepower of the source in the given direction, and inversely proportional to the square of the distance from the source to workplane.

Because the lack of 6 feet light fixtures in the local market, 4 foot fixture will be used and connected in series to coordinate with the length of workbenches of each row. The data of task-lighting system are provided as follows:

a. No. of workbenches @ 5 benches/row, 12 rows in total	= 60 pcs
b. No. of required task lights, 38 W, EE lamps	= 84 lamps
c. Illumination level to be obtained	= 50 FC
d. Lamp output @ 70% of rated life	= 2,500 lumen
e. Average life of lamps, 38-watt	= 8,000 hrs
f. Average life of ballasts @ 10 hrs per lit	= 30,000 hrs
g. Operating hours per year	= 2,482 hrs
h. Cost of electricity per kwh	= NT$2.01
i. Demand charge per kw	= NT$141.6
j. Cost of light fixture 4-foot	= NT$486/ea
k. Cost of lamp 38-watt EE lamp	= NT$38/lamp

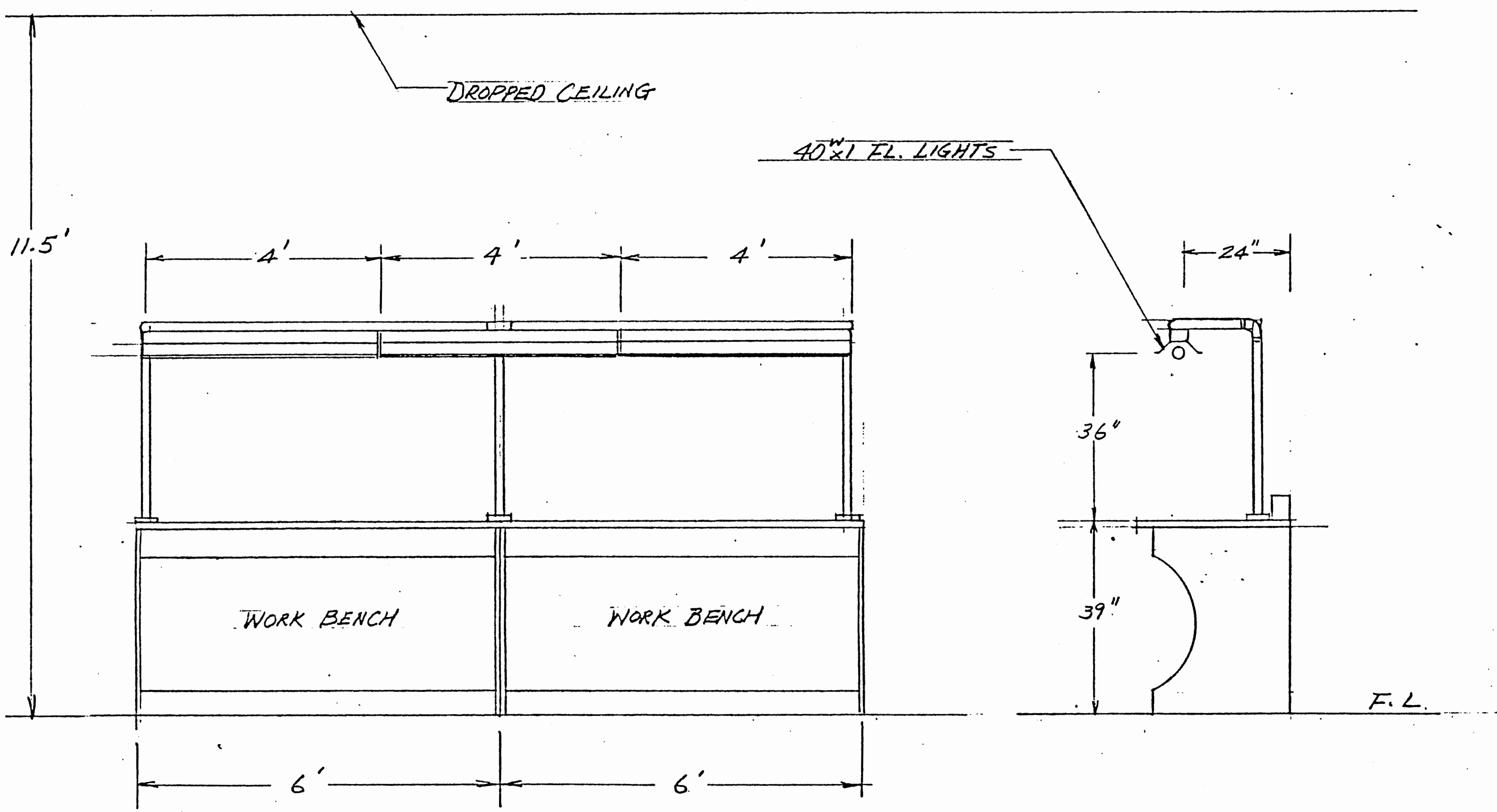


FIG 3.2a – PROPOSED TASK LIGHTS S: 1/30

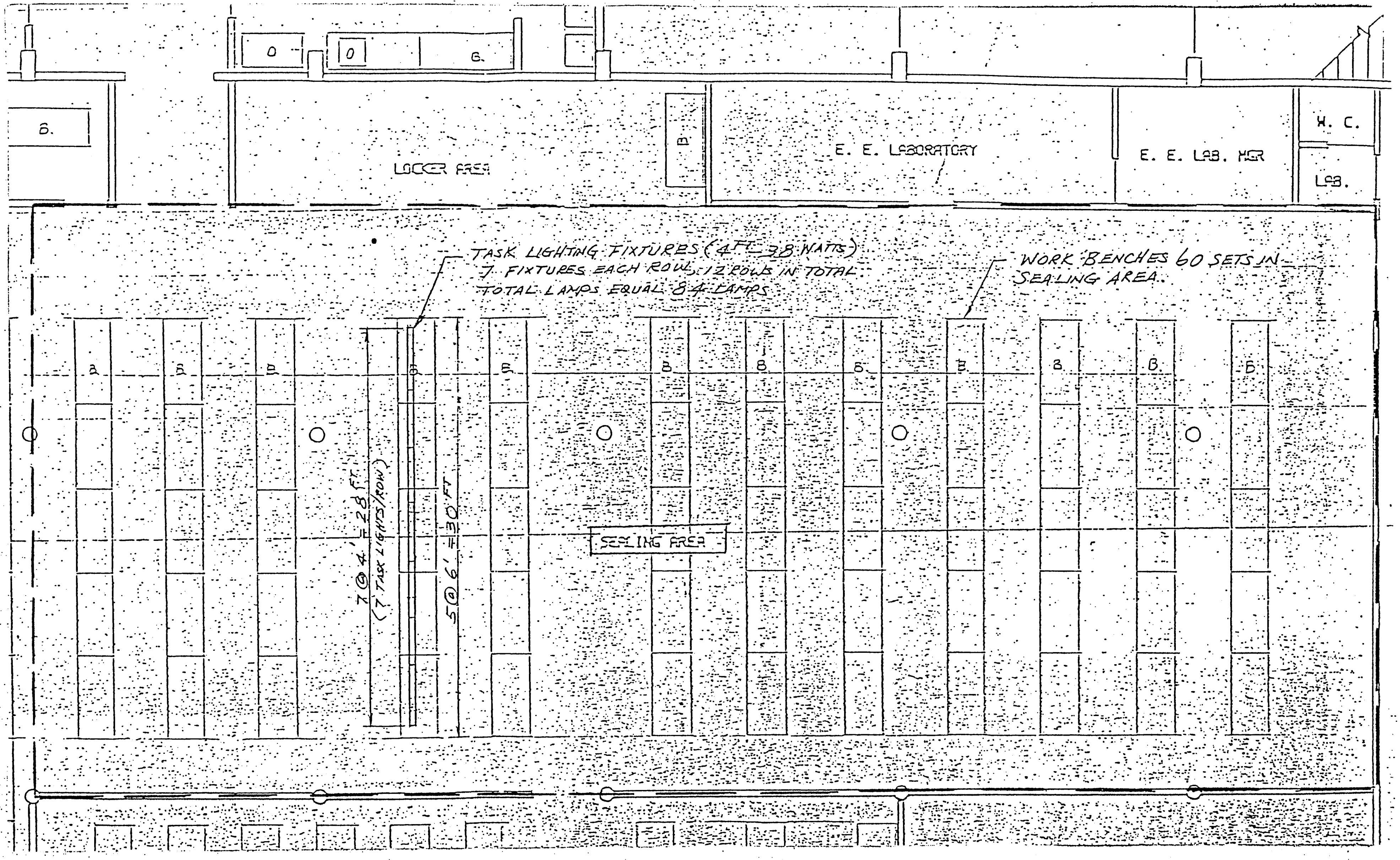


Fig3.2b - Proposed task lighting layout

L. Cost of ballast, 4-foot fixtures = NT$210/ea

It has been calculated that the total energy consumption will be 11,481 kwh/yr. the annual operating costs would be NT$32,903/yr.

Economic justifications

The economic justifications between current general lighting and proposed task lighting systems are based on a 10 years planning horizon and the useful life of ballasts is assumed to be 10 years.(The life of light fixtures normally last longer than ballasts). Because the current lighting system has been installed for 7 years, the potential replacement cost of ballasts has to be taken into considerations.

1. The annual operating/maintenance costs of current lighting system = NT$172,023/yr
2. The annual operating/maintenance costs of new task-lighting system = NT$32,903/yr
3. Reduction in operating costs = NT$139,120/yr
4. Implementation costs of new task-lighting system = NT$91,106
5. Simple payback period = 0.65 years

The above detailed calculations are also shown in Appendix B.

Analysis for combined lighting system

In order to provide comfort environment, and also reduce the operating cost of lighting system. A supplementary lighting system in conjunction with new task lighting system has been considered. According to the requirement of IES (Illuminating Engineering Society), the minimum illumination level of supplementary lights has to be not less than 20 foot candles or 20 percent of illumination level of task lights. (Whichever is greater)

The supplementary lighting can be implemented by using some of the current general lights with wiring modifications. Fig.3.3 presents the proposed supplementary lighting layout. It has been calculated that the number of lamps required for supplementary lights will be of 18. Detailed calculations are shown in Appendix C.

Economic justifications between the existing general lighting and new combined lighting systems are based on 10 years planning horizon and 10% of MARR (Minimum Attractive Rate of Return).

1. Annual operating/maintenance cost of current lighting system = NT$172,023
2. Annual operating/maintenance cost of new combined lighting system = NT$55,442
3. Potential annual dollar savings in operating cost = NT$116,581

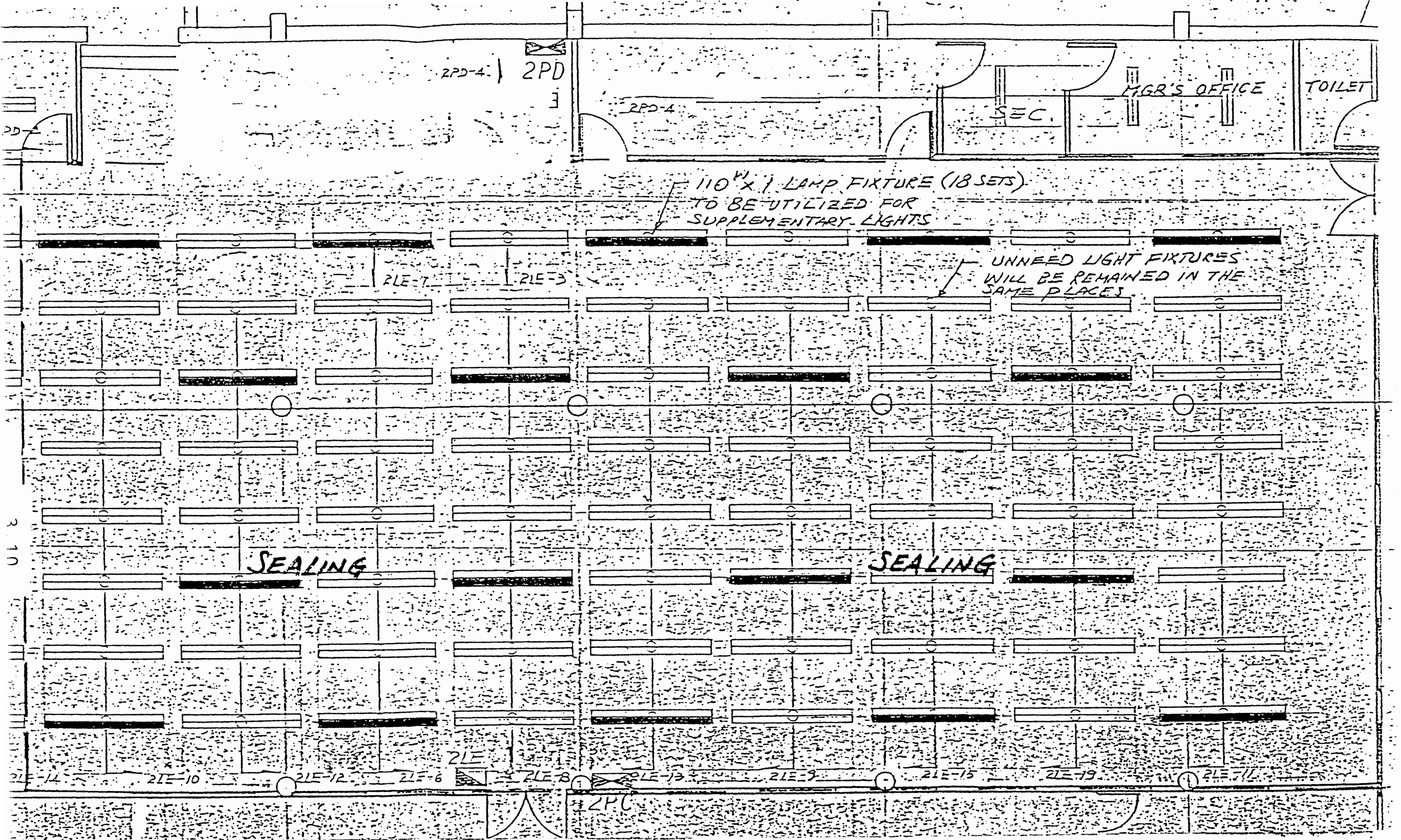


Fig3.3 - Proposed supplementary lighting layout

4. Implementation cost of new combined lighting system = NT$94,106

5. Simple payback period = 0.8 yrs

The above detailed calculations are presented in Appendix D.

Comparison of general lighting and task lighting systems

1. General lighting provides a uniform level of illumination on the entire area which permits complete flexibility in task location.

2. General lighting system requires more luminaries and provides unneeded high illuminations for non-task areas (such as aisles). Which results in higher energy consumption and higher operating costs.

3. Task-lighting system provides a high level of illumination on the workplanes with fewer luminaries and less power consumptions. The operating cost is much less than that of the general-lighting system.

4. The task lighting is more accessible to fixture maintenance and lamp replacement than that of general lighting system.

5. Task-lighting system may cause annoying glare and fatigue for nearby workers if the inadequate lights installation happens.

Recommendation

To prevent excessive changes in adaptation the task lighting system, it should be used in conjunction with general lights; that is at least 20 percent of the task lighting level, it then becomes supplementary. This combined type of lighting system shall be achieved by retaining 18 sets of current lighting fixtures with 1-lamp in each fixture. By adapting this system, the annual operating cost will end up to NT$55,442 and results in an annual savings of NT$116,581. This will give a payback period of 0.8 years.

Conclusion

There are many other available methods to save energy on lighting systems. Such as using energy-efficient lamps, solid-state ballasts, and day lighting. Connected load can be reduced and light level increased by cleaning fixtures and replacing existing fluorescent lamps with energy-saving lamps. When possible, walls and ceilings should be painted with light colors for better reflectance.

However, direct glare, reflected glare, illumination uniformity, diffusion, and color affect the overall degree of comfort provided by the lighting installation and influence its effectiveness in creating conditions that result in efficient, accurate performance of visual task.

APPENDIX A

Calculations of Existing General Lighting System

Demand load

= (Total input watts/lamp) (No. of lamps) (watts to kw conversion)

= (110 w x 1.25) (144 lamps) (1 kw/1000 w)

= 19.8 kw

KWH consumption in lights

= (demand load) (hrs of operation)

= (19.8 kw) (2482 hrs/yr)

= 49,143 kwh/yr

Demand in air conditioning

= (19.8 kw)(3413 Btu/kwh)(1ton-hr/12000 Btu)(1.1 kw/Rt)(.5)

= 3.1 kw

KWH consumption in air conditioning

= (demand load) (hrs of operation) (3413 Btu/kwh) (1 ton-hr/12000 Btu) (performance efficiency of A/C system) (heat transmission of dropped ceiling)

= (19.8 kw) (2482 hrs/yr) (3413 Btu/kwh) (1 ton-hr/12000 Btu) (1.1 kw/1 RT) (0.5)

= 7,687 kwh/yr

Total KWH consumption

= 49143 + 7687

= 56,830 kwh/yr

Energy cost

= (Total kwh consumption) (cost of electricity) + (demand load) (demand charge) (12 mos/yr)

= (56830 kwh/yr) ($2.01/kwh) + (19.8 + 3.1 kw)($141.6/kw) (12 mos/yr)

= NT$153,140/yr

Lamp replacement cost

= (No. of lamps) (cost per lamp) (1/average life of lamps) (hrs of operation)

= (144 lamps) ($200/lamp) (1/10000 hrs) (2482 hrs/yr)

= NT$7,148/yr

Equivalent annual cost of replacing ballasts at end of year 3.

= (cost/ballast + installation labor cost/ballast) (No. of ballasts) (P/F, 10%, 3 yrs) (A/P, 10%, 10 yrs)

= (NT$700 + NT$50) (128 ballasts) (0.7513) (0.1627)

= NT$11,735

Total annual operating cost

= (energy cost) + (lamp replacement cost) + (ballasts replacement costs)

= NT$153140 + NT$7148 + NT$11735

= NT$172,023/yr

Note: The performance efficiency of the existing air conditioning (A/C) system is the ratio of total power consumption of the system and the total tons of refrigeration. The power consumption of the system includes the compressor of chiller unit, fans of air handling units, water pumps, and cooling tower fan.

APPENDIX B

Calculations of Task Lighting System

Demand Load

= (38 w/lamp x 1.25) (84 lamps) (1 kw/1000 w)

= 4.0 KW

KWH consumption in lights

= (4.0 kw) (2482 hrs/yr)

= 9,982 kwh/yr

Demand in air conditioning

= 4.0 kw x 3413 x 1/12000 x 1.1

= 1.2 kw

KWH consumption in air-conditioning

= (4.0 kw) (2482 hrs/yr) (3413 Btu/kwh) (1ton-hr/12000 Btu)

(1.1 kw/1RT) (0.5)

= 1,553 kwh/yr

Total KWH consumption

= 9928 + 1553

= 11,481 kwh/yr

Energy cost

= (11481 kwh/yr) ($2.01/kwh) + (4.0 + 1.2 kw) ($141.6/kw) (12 mos/yr)

= NT$31,913/yr

Lamp Replacement Cost

= (84 lamps) ($38/lamp) (1/8000 hrs) (2482 hrs/yr)

= NT$990/yr

Total annual operating cost

= NT$31913 + NT$990

= NT$32,903/yr

Implementation cost

= (cost of new light fixtures) + (new pipe brackets) +

(installation labor cost) + (misc. & overhead 10%)

= (NT$486 x 84 lamps) + (NT$400 x 60 sets) + (NT$300 x 60set)

+ (NT$8282)

= NT$91,106

Annual dollar savings in operating costs

by using task lights

= NT$172023 - NT$32903

= NT$139,120/yr

Simple payback period

= Implementation cost/annual dollar savings

= NT$91106/NT$139120

= 0.65 years

Return on investment (ROI)

= (monies saved in energy cost)/(investment in energy-saving

system)

= 139120/91106

= 1.53

APPENDIX C

Calculations of required supplementary lights

Calculations:

1. A minimum illumination level of 20 foot candles is required for supplementary lights. Working surfaces are 3 feet from the floor. Utilizing the equation to calculate the RCR (Room Cavity Ratio) results in the following:

   RCR = (5) (Height from the working surface to luminaries) (Room length + Room width) / (Room length) (Room width)

   = (5) (5) (41 + 87) / (41) (87)

   = 1.0
2. The CCR (Ceiling Cavity Ratio) need not be considered as the luminaries are ceiling recessed.
3. According to the Table 3.1, the WR (Wall Reflections) and BCR (Base Ceiling Reflectance) are 80%. Since the current luminaries are ceiling recessed, the ECR (Effective Ceiling Reflectance) is also 80%.Table 3.2
4. From Table 3.3, a CU (Coefficient of Utilization) of 0.65 will be utilized as the fluorescent lamps in prismatic lens fixture.
5. For fluorescent lamp in prismatic lens fixtures in a "clean environment" that are cleaned every 24 months, from Table 3.4, the LLF (Light Loss Factor) will be 0.83.
6. Based on the above figures, the number of lamps (110-watt) required to be calculated from the following equation.

Number of lamps = (required level of illumination) (Area to be lit) / (CU) (LLF)(lamp output at 70% of rated life)

= (20) (41 x 87) / (.65) (.83) (7500)

= 18 lamps

Since one lamp will be placed in each fixture, 18 current fixtures will be utilized as supplementary lights. The proposed layout is shown in Appendix E. The balance of lighting fixtures will still be remained at Sealing area for the reason of saving the cost of removing them.

APPENDIX D

Calculations of combined lighting system

Supplementary general lights

Demand load

= (110 W X 1.25) (18 lamps) (1 kw/1000 w)

= 2.5 kw

KWH consumption in lights

= (2.5 kw) (2482 hrs/yr)

= 6,205 kwh/yr

Demand in air conditioning

= 2.5 kw x 3413 x 1/12000 x 1.1 x 0.5

= 0.4 kw

KWH consumption in air conditioning

= (2.5 kw) (2482 hrs/yr) (3413 Btu/kwh) (1 ton-hr/12000 Btu)

(1.1 kw/1RT) (0.5)

= 970 kwh/yr

Total KWH consumption

= 6205 + 970

= 7,175 kwh/yr

Energy cost

= (7175 kwh/yr) (NT$2.01/kwh) + (2.5 + 0.4 kw) (NT$141.6/kw)

(12 mos/yr)

= NT$19,995/yr

Lamp replacement cost

= (18 lamps) (NT$200/lamp) (1/10000 hrs) (2482 hrs/yr)

= NT$894/yr

Ballast replacement cost

= (NT$700 + NT$50) (18 ballasts) (P/F,10%,3 yrs)

(A/P,10%,10 yrs)

= ($750)(18)(.7513)(.1627)

= NT$1,650/yr

Additional operating cost for supplementary lights

=$19995 + $894 + $1650

= NT$22,539/yr

Total operating cost of combined lights

= $32903 + $22539

= NT$55,442/yr

Implementation cost

= (Implementation cost of task lights) + (Implementation

cost of supplementary lights)*

= $91106 + $3000

= NT$94,106

Annual dollar savings from using combined lighting system

= $172023 - $55442

= NT$116,581/yr

Simple payback period

= $94106/$116581

= 0.8 yrs

Return on investment (ROI)

= 116581/94106

= 1.24

* The implementation cost of the supplementary lights will include disconnecting the one extra ballast in each light fixture (2 ballasts each for existing fixtures), and modifying the wiring circuit for the indicated 18 fixtures.