EVALUATION OF CS_2 RECOVERY FROM RAYON MILLS

India
March 13 - 23, 1994

Prepared for:

US - ASIA ENVIRONMENTAL PARTNERSHIP

WORLD ENVIRONMENT CENTER

DISCLAIMER

This project was sponsored by the U.S. Agency for International Development through WEC's Cooperative Agreement in support of the U.S. - Asia Environmental Partnership (US-AEP). The opinions expressed herein are the professional opinions of the author and do not represent the official position of the Government of the United States of America or the World Environment Center.

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I. EXECUTIVE SUMMARY

From March 13 through 29, 1994, Dr. Avi Patkar of Radian Corporation visited several cities in India to evaluate the applicability of a carbon disulfide (CS_2) recovery system in India's rayon mills. A typical rayon mill emits over 400 tons/year of CS_2 from the spinning machines where CS_2 is used as a solvent in the process. The air flows are high (100,000 cubic meter per minute (ft^3/min)) and CS_2 concentration is very low (80-100 parts per million (ppm)), therefore, large air flows are used with hoods on the machines to direct the CS_2 away from the workers. At present, there has been no commercial installation for CS_2 recovery from rayon mills. Radian has developed a recovery system which can be used in this application. This report gives the details of the findings based on visits to rayon mills and other companies.

The primary findings are:

1. The current level of CS_2 concentration (80-100 ppm) is too low to be economically viable for the absorption/stripping recovery system. The low concentration will require large air and solvent handling systems in order to achieve 90% removal. The cost of the control system will be very high, and the credit compiled for recovered CS_2 will not offset the total annual operating cost%.

2. It is imperative to design a better CS_2 capture system which will increase its concentration in the exhaust air to 800-1000 ppm.

3. The capture system design developed by Radian and provided in this report should be implemented on one machine and tested for its effectiveness.

Funding for this project was provided through a Cooperative Agreement between the World Environment Center (WEC) and the United States-Asia Environmental Partnership (US-AEP).

II. INTRODUCTION

This environmental Buwiness Exchange (EBE) was sponsored by the US-AEP through its Cooperative Agreement with WEC. The purpose of the EBE was to evaluate the applicability of a carbon disulfide (CS_2) recovery system in that country's rayon mills. Dr. Avi Patkar, P.E. Senior Staff Engineer from Radian's Cincinnati, Ohio office visited India as the EBE participant in India. He was assisted by Mr. Ramesh Ukidve of Sudarshan and Mr. P.S. Rao, a consultant from Bombay, India.

At present, there is no cost-effective system to recover CS_2 from rayon mills. CS_2 emission will soon be regulated by the Central Pollution Board. Radian has identified a potential absorption/stripping technology (RABS) for recovery of CS_2 from rayon mills in India. Sudarshan Chemical Industries Ltd. (Sudarshan) of Pune, India, is a leading manufacturer of dye intermediates. Sudarshan has a partnership agreement with Radian for the use of environmental services and technologies for chemical and allied industries. Under this agreement, Sudarshan will identify potential consultancy projects in pollution control and utilize Radian's expertise to market environmental consulting services.

Sudarshan has submitted a proposal to th U.S. Agency for International Development (USAID) to conduct a pilot plant study of the RABS system at a rayon mill in Bombay under the Trade in Environmental Services and Technologies (TEST) program. If the project is funded by USAID, Radian will supply the process design of the pilot plant, and Sudarshan will conduct the pilot study at one rayon plant. Susdarshan had identified Mr. Rao as the consulting mechanical engineer who has over 25 years of experience in machine design.

The primary purpose of this exchange was to visit the rayon mills with a mechanical engineer who ould design a capture system which would achiee the following goals: keep worker exposure below the Permissible Exposure Limit (PEL); reduce the air flow required to evacuate the CS_2 in the range of 800-1000 ppm.

Additional objective of the EBE included: visit Sudarshan to discuss the pilot plant design; meet dye manufacturers; identify a potential fabricator fo the pilot plant; meet Engineers India Ltd. (EIL) representatives to discuss the cost of full-scale unit; and meet USAID officials in New Delhi.

III. FINDINGS

A. INTRODUCTION

This section describes a brief description of the proposed process, and the critical need for designing a better capture system for the CS_2 vapors.

Process Description

(A detailed process flow diagram for the proposed CS_2 recovery system is shown in Figure 1, Appendix A.)

CS_2-laden air from the rayon plant will be conducted through a fan (F-1) to a cross flow, 3-stage horizontal absorption column (AB-1). CS_2 will be absorbed in an organic solvent absorption fluid as it passes through the column. The absorption solvent, now laden with CS_2, will pass through a holding tank (T-1) prior to being pumped (P-1) to the tripping section of the recovery system.

The CS_2-laden absorption solvent passes through two heat exchangers (H-1 & H-2) prior to entering the stripper (ST-1). The first heat exchanger (H-1) uses "clean solvent" from the bottom of the stripping column to preheat the incoming absorption solvent. This "clean solvent" is also pumped (P-2) back to the absorber for reuse. Liquid nitrogen (T-1) is vaporized onsite and used in the stripper to remove CS_2 from the organic solvent. The liquid nitrogen vaporizer (H-4) uses chilled brine from a brine tank (T-3) for cooling. This brine is returned to the CS_2 stripper condenser (H-3) for CS_2 recovery from the stripper outlet. The stripping column is operated in a counter current mode with vaporized nitrogen entering the bottom of the tower, and CS_2-laden solvent entering the top of the tower. Stripping is done under vacuum by using a vacuum pump (VP-1). As CS_2 is stripped from the organic solvent, it leaves the top of the stripper and is condensed in the brine cooled condenser (H-3). Noncondensibles from the condenser tail gas are ducted back to the absorber for additional treatment. Recovered CS_2 is collected in a condensate tank (T-4) and stored for reuse.

Capture System

Because the main concern has been to keep the ambient work-place concentration below the Permissible Experience Limit (PEL) -- as defined by the U.S. Occupational Health and Safety Agency (OSHA), the rayon mills evacuate the air from the machines with large air flows of concentrations in the range of 80-100 ppm. The recovery system described above can be cost-effective only if the vapor-phase concentration of CS_2 is 800-1000 ppm.

B. RAYON INDUSTRY/CS_2 CAPTURE

The two main rayon manufacturers in the Bombay area are Century Rayon and National Rayon. Both plants were visited and the machines were inspected. The Centry Rayon representative, Mr. Acharya, highlighted improvement measures to existing capture system.

Objective: To design a hood and capsule system to contain the gases (CS_2/HS_2) emitted from the bath during the process of rayon forming under a low vacuum in the capsule, ensuring a minimum of air ingress into the system.

Activities

1. Discussions with Dr. Patkar of Radian Corporation and Mr. Ukidve of Sudarshan.
2. Visit to Century Rayon and discussions with plant personnel.
3. Visits to National Rayon Corporation (NRC) and discussions with plant personnel.

Present Status: The spinning machine section is a hall which houses around 100 spinning lines. Each line has 2 rows of 64 pots where the bobbins are wound arranged back to back on a frame. The rayon threads are formed in the bath solution and are guided to the rotating bobbins.

The CS_2/HS_2 gas emitted from the bath solution is removed by individual suction ducts located at several points on the frame itself just above the bath level and connected to the stack. The remaining traces are removed by blowing fresh air while simultaneously exhausting air at the bottom, and maintaining a negative pressure in the room. The gases are exhausted through the stack.

The following process interruptions were observed:

- Breakage of threads - This is more frequent in finer threads. On an average, 2 to 5 thread breakages occur per line per hour. The machines are not stopped during restoration and only the individual sections are attended to. The time gap is of the order of 20 to 30 seconds.

- Replacement of broken glass thread guide - This is very rare. The machines are not stopped during restoration and only the individual sections are attended to.

The time gap is of the order of 40 to 60 seconds since it involves both replacement of the glass component and also thread restoration.

- Replacement of the filled bobbins (doffing) - Here the machine is closed and the changing is done at several points simultaneously. All the sections are required to be kept open. This occurs 1 to 2 times per shift and the time gap may be 5 to 10 minutes.

It was also noted during discussions that in the event of a closed chamber the workers would have to face a sudden gush of gas as soon as the cover was opened. This possibility also needs to be addressed. The opening and closing of the capsule would have to be such that there should be not operator fatigue. In addition, it noted that all the spinning machines were not identical, and the structures may have to be altered to suit individual machines. After initial trials with one unit, the finer aspects such as the standardization of major components for the other units can be considered.

System Requirements: Based on the data collected earlier, the design should meet the following guidelines and should be made to fit unit No. 66 in the plant at NRC:

1. The system should be reasonably leakproof and maintain a light vacuum, as it does now.

2. The capsule has to be opened frequently for attending process interruptions like thread snapping, replacement of broken guides, and replacement of bobbins (doffing).

3. The system should have good visibility in the working area. Acrylic sheet panels are proposed to be used in a stainless steel main frame. The top also will be covered with acrylic sheets and will be directly below the lights. This will ensure that the light will go through the clear plastic and illuminate the machine.

4. The system should be corrosion resistant, and should meet specific fire prevention standards. The operating system is proposed to be pneumatically operated and the frames will be made of stainless steel 316.

New Design: The proposed new system consists of a separate prefabricated light superstructure added on to the existing frame to form an effective hood and capsule. To keep the air dilution at a minimum, the entire length of the plant has been divided into convenient sections of approximately 1.4 meters each which can be independently opened and closed. (See detailed drawing in Appendix A).

The new design has following advantages:

- Most of the work will be pre-fabricated and does not require any stoppage of the plant.
- Plant shut down time for modifications would be a minimum. The only alterations would be drilling and tapping at selected points on the frame since the wetted area of the lead lined tray cannot be drilled.
- The support structure is on the top of the existing frame, and is well away from the area of any possible chemical splash.
- The pneumatic pipe lines are run along the support frame.
- Dismantling of the additions and restoring the plant to its original condition will be very easy and speedy should the occasion arise at a future date.
- The doors are designed to open in two stages: initial lifting from the sealing gasket and then sliding open. This prevents early wear of the sealing gasket.

The design has incorporated all the above specified points. However, the following points can be decided upon only after installation on one machine.

- Assessment of the effectiveness of the sealing, at present there is no facility for this.
- Lighting conditions inside cannot be predicted and suitable action will have to be decided on the spot.
- The sealing of the joints between the new add on frame and the existing structure will also have to be done on the spot by acid-proof rubber gaskets.

C. VISITS TO AHMEDABAD AND NASIK

Dr. Patkar, accompanied by Sudarshan engineers, visited three dyestuff manufacturers in Ahmedabad. These companies supply dyes for textile mills which use rayon and other fibers. The discussions with the dyestuff companies centered around their environmental emissions and potential solutions, as well as the possible identification of potential fabricator for the pilot plant. Spicer India Ltd., a subsidiary of DANA Corp., is located in Nasik and supplies machine parts to industry. They are planning to have a plant in Pune and have evaluated fabricators in the area. Mr. Hardikar of Spicer India was contacted for information on fabrication in the Pune and Nasik area. The information was discussed with Sudarshan engineers.

D. VISIT TO NEW DELHI

Engineer India Ltd (EIL) is a design engineering firm based in New Delhi employing over 3,000 people. Radian has recently entered into agreement with EIL to market its environmental services to refineries and petrochemical plants. EIL has the capability to perform detailed engineering designs of large-scale plants. The possibility of working with EIL for full-scale design of the RABS system was discussed Mr. Anil Jain and Mr. T.P. Ranagamani. Mr. Amitabha Ray of USAID/New Delhi of Environment, Energy and Enterprise was also contacted.

E. COMPANIES IN PUNE

The visit to Sudarshan offices in Pune occurred on March 26th and 27th. The people contacted include Mr. Ukidve (Sr. Manager), Dr. R.J. Rathi (Managing Director), Mr. K.L. Rathi (V.P. Operations), Mr. Pradeep Rathi (V.P. Finance and Marketing). The technical feasibility of the Radian absorption shipping system (RABS) was discussed. Dr. Rathi suggested exploring other applications for the technology. Dr. Patkar informed him that the same system can be applied to recovery of xylene for automotive and appliance spray booths.

The pilot plant proposal for the TEST program, and the process design was discussed with Mr. Ambekar (Sr. Process Engineer).

A visit also took place with Dr. Vikas Nadkarni of Vikas Technologies. He has a Ph.D. in Chemical Engineering from the University of Delaware and has worked with DuPont and other companies in the U.S. for 6 years. Dr. Nadkarni returned to India in 1980 and was the Deputy Director for National Chemical Laboratory. He has now become a consultant to chemical and allied industries. Discussions focused on the applicability of RABS technology to other industries.

F. CONTACTS WITH INDUSTRIAL CREDIT AND INVESTMENT CORPORATION OF INDIA

The two officials with the Industrial Credit and Investment Corporation of India (ICICI), Bombay, who will review the TEST proposal were on a visit to the U.S. Mr. Advani was contacted by telephone and briefed about the trip. Dr. Patkar met with Mr. Harinathan and Mr. Palkar in Washington D.C. on April 7th, 8th and 9th where both of them were briefed on the developments of the trip. Mr. Amitabh Ray, who was the leader of the contingent from India visiting the U.S., was also briefed.

IV. CONCLUSIONS AND RECOMMENDATIONS

As a result of the trip, Dr. Patkar made the following conclusions and recommendations.

Conclusion 1: **The current level of CS_2 concentration (80-100 ppm) is too low to be economically viable for the absorption/stripping recovery system.**

Most of the rayon executives, particularly Mr. Ultamchandahi of Century Rayon and Mr. Maheshwari of National Rayon, felt that the CS_2 concentration is too low for a recovery system. They have consulted with some German companies which have cited the need to raise concentration to over 1000 ppm. Radian's RABS system will also be economically viable only in the range of 800-1000 ppm.

In order to be economically viable, a capture system would need to be designed to achieve outlet concentrations of CS_2 in the range of 800-1000 ppm.

Conclusion 2: **It is imperative to design a better CS_2 capture system which will increase its concentration in the exhaust air to 800-1000 ppm.**

The proposed Radian design will be able to accomplish this level of concentration.

Recommendation 1: **The capture system design prepared by Mr. Rao should be implemented on one machine and tested for its effectiveness.**

Mr. Amudhan of National Rayon has offered to be the host site.

Recommendation 2: **The RABS pilot unit should be made flexible to apply for xylene recovery from automotive and appliance spray bottles.**

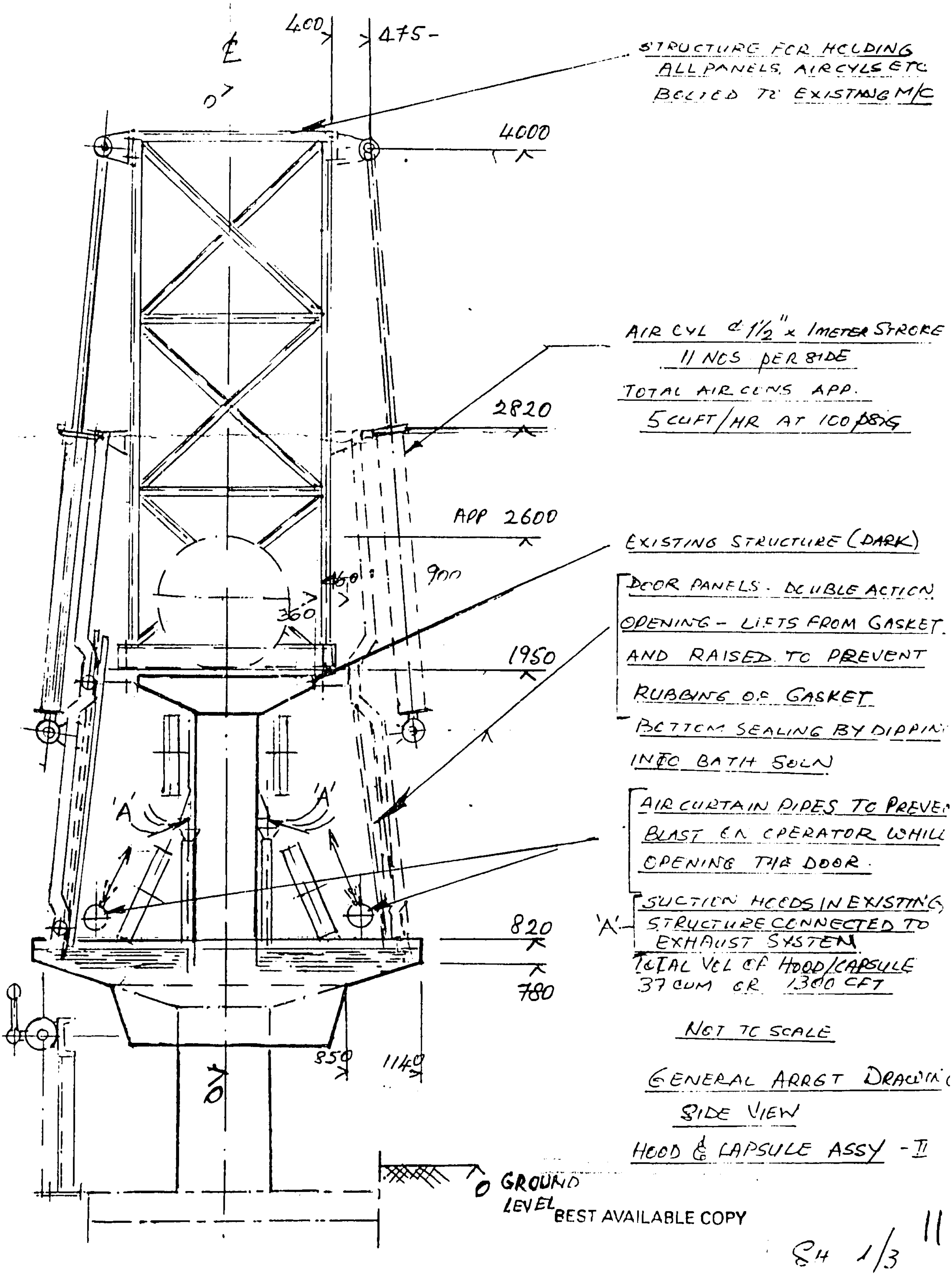
This would demonstrate wider applicability of the RABS system. Radian has already demonstrated this on bench-scale in a lab in North Carolina.

Recommendation 3: **<u>The RABS pilot plant project, if funded by TEST, should include demonstration at one rayon mill and one spray painting booth.</u>**

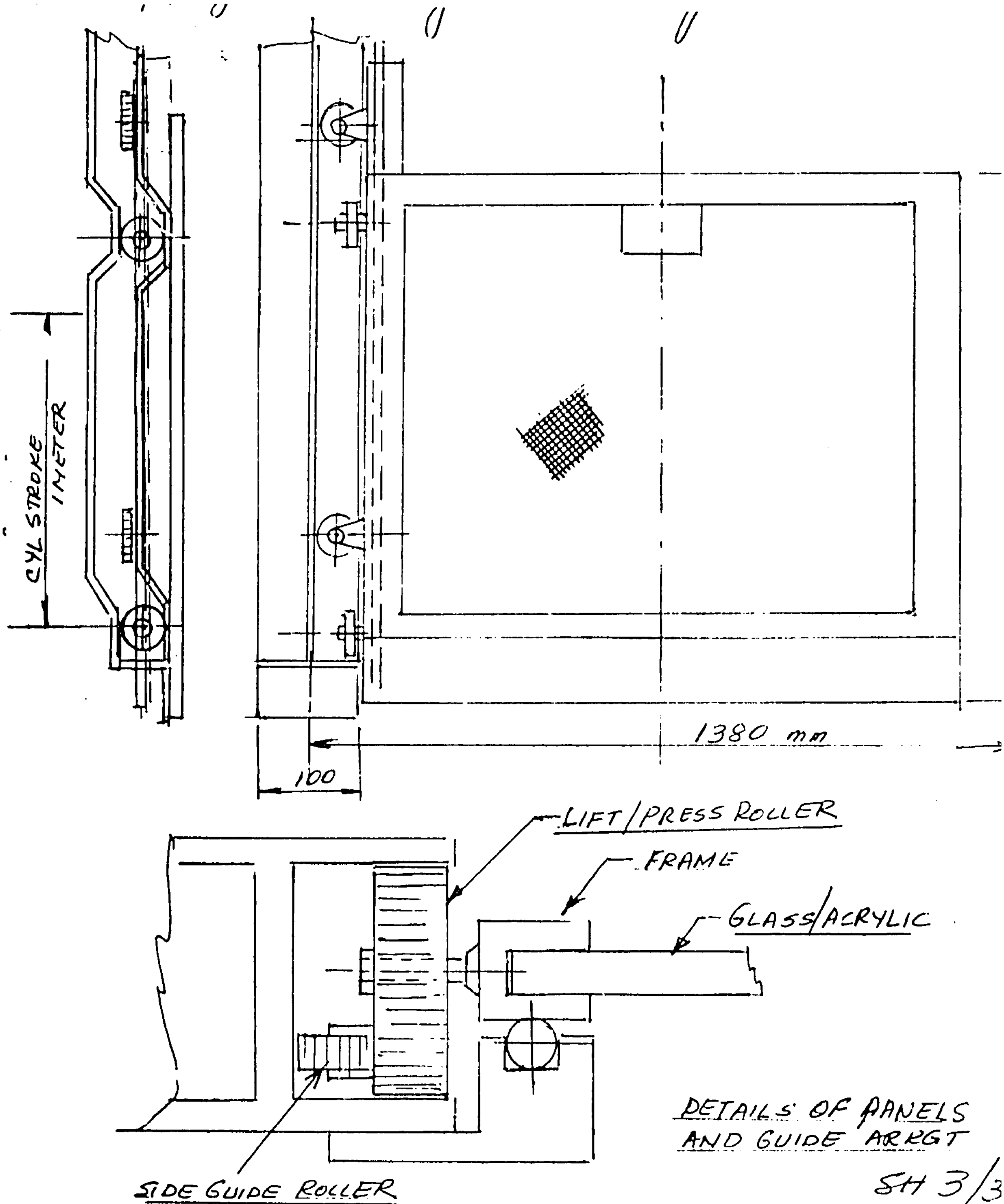
APPENDIX A

ENGINEERING SKETCH FOR CAPTURE SYSTEM

A 7/348 M. G. Colon.
Gandhinagar, BANDRA East
BOMBAY 051



A-37/348, M I G Colony,
Gandhinagar, BANDRA East,
BOMBAY-400 051.

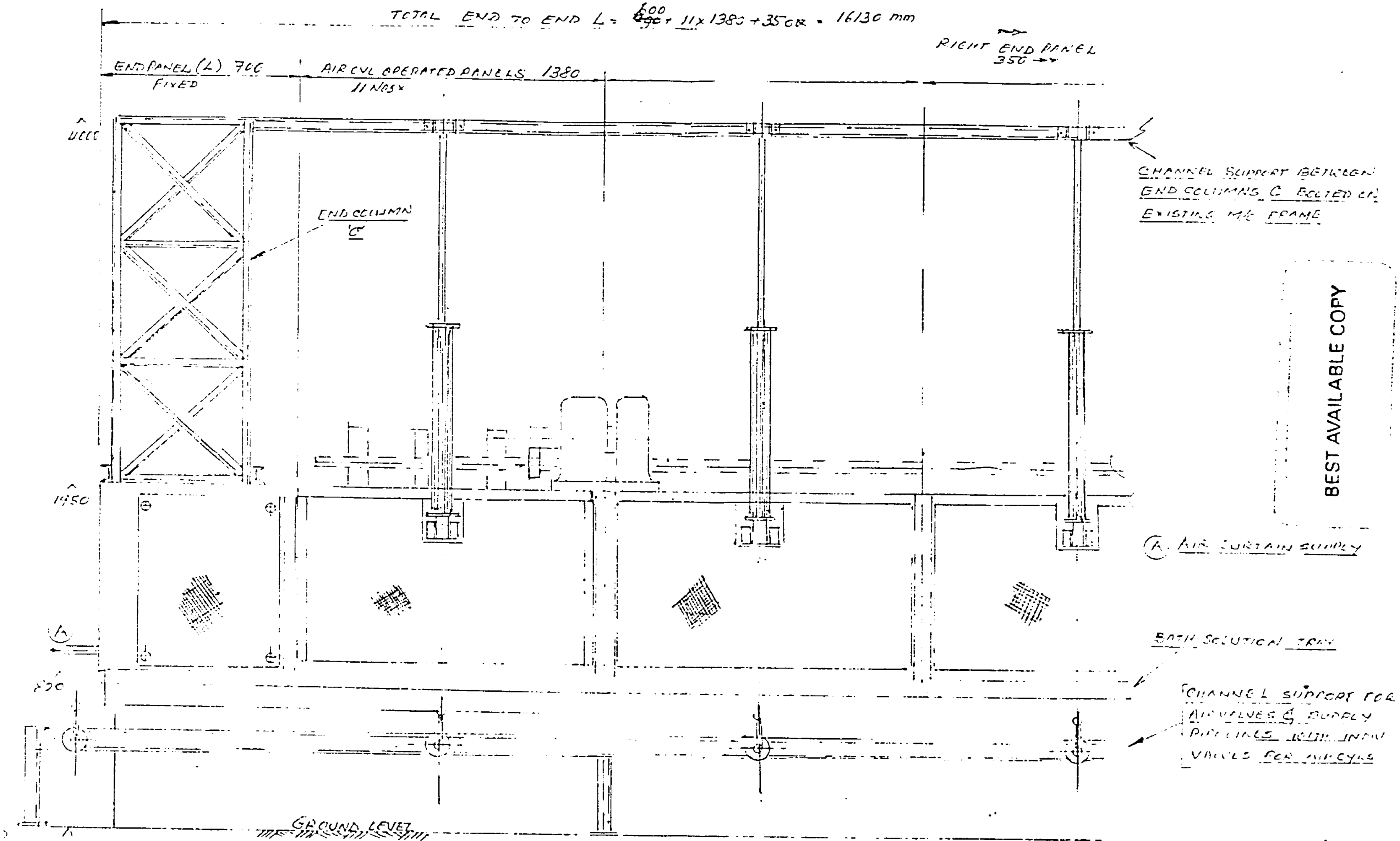


DETAILS OF PANELS
AND GUIDE ARRGT

SH 3/3

NOT TO SCALE ; DIMENSIONS ONLY
TENTATIVE

27.3.1994

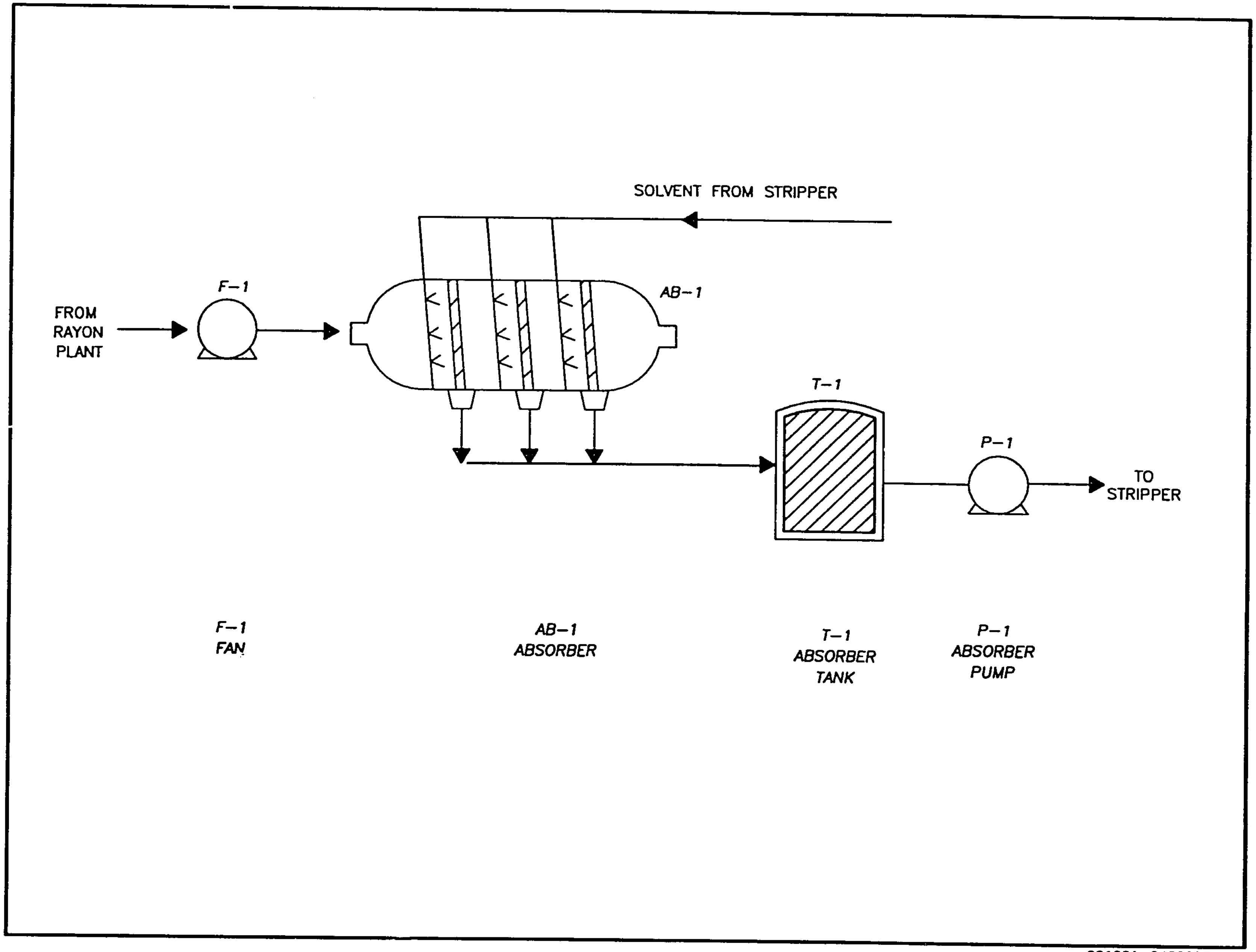


GENERAL ARRANGEMENT DRAWING - II

SH 2/3
27.3.1994

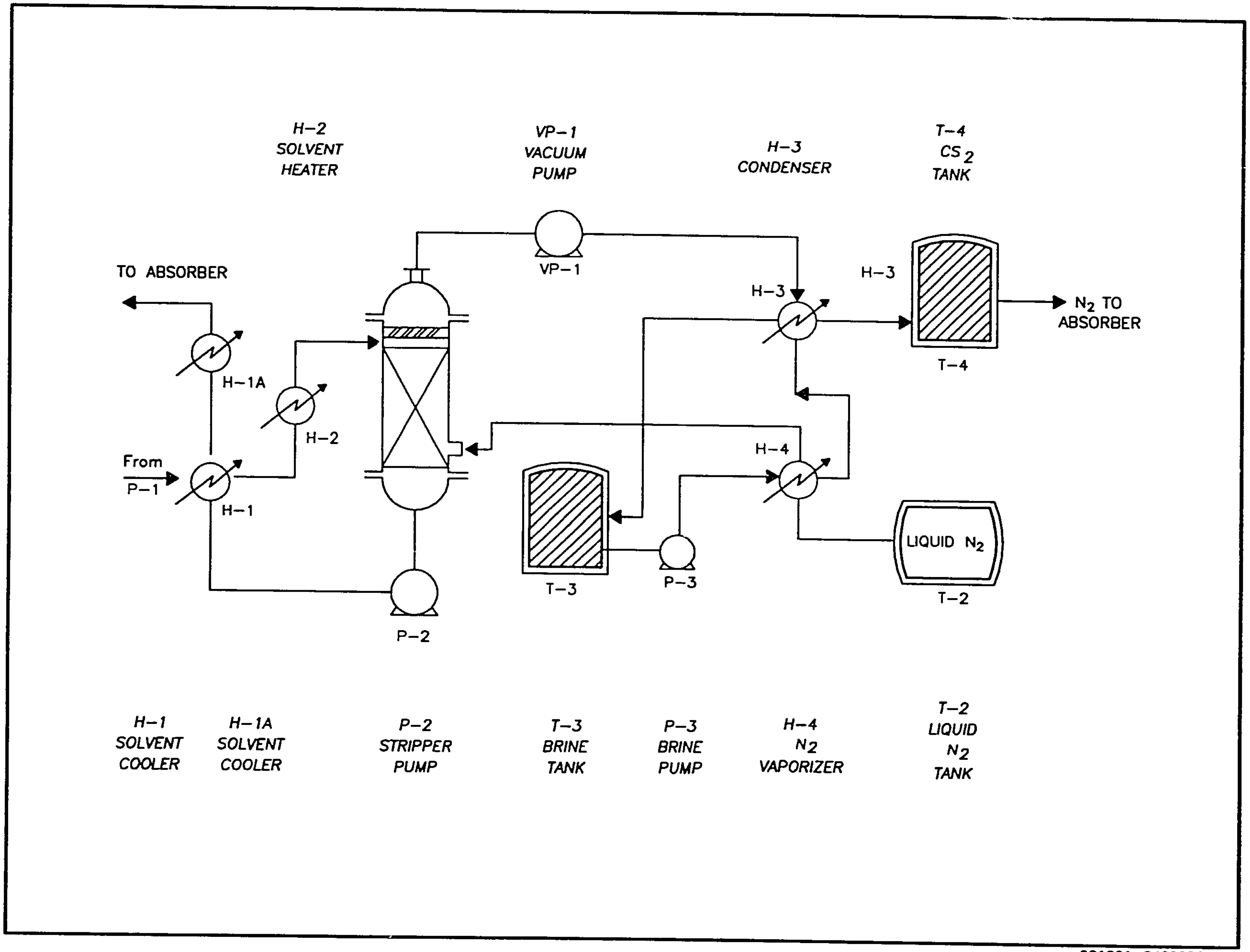
ENGINEERING SKETCH FOR CAPTURE SYSTEM

Figure 1. Schematic Flow Diagram of RABS System



901001-9400023-MIL

PROCESS FLOW DIAGRAM: CS_2 RECOVERY SYSTEM-ABSORBER



901001-9400022--MIL

PROCESS FLOW DIAGRAM: CS_2 RECOVERY SYSTEM-STRIPPER

APPENDIX B

ITINERARY

ITINERARY

DATE	CITY	FACILITIES
March 13-16	Bombay	Mr. P.S. Rao, Mr. Ukidve Century Rayon, National Rayon
March 17-19	Ahmedabad	Dintex, Dyechem, Rassayanam, Mayur
March 21-22	Nasik	Spicer India
March 23-25	New Delhi	Engineers India, Ltd. USAID/New Delhi
March 26-27	Pune	Sudarshan, Vikas Technologies
March 28-29	Bombay	Mr. P.S. Rao, Mr. Ukidve Century Rayon, National Rayon

APPENDIX C

PERSONS AND ORGANIZATIONS VISITED

PERSONS AND ORGANIZATIONS VISITED

City	COMPANY	Person
Bombay	Sudarshan	Mr. P.S. Rao, Mr. R. Ukidve
Bombay	Century Rayon	A.M. Vaidya, H.G. Uttamchandani, R.M. Acharya, V.K. Jain, Dr. V.S. Chincholkar
Bombay	National Rayon ICICI	M.K. Maheshwari, K. Amudhan, K. Harinathan, A. Palka
Ahmedabad	Dintex, Rasayanam Mayur	D.S. Sha, D. Babaria Mayur, B. Patel
Pune	Sudarshan	R. Ukidve, K.L. Rathi, Dr. R.J. Rathi, P.R. Rathi
	Vikas Technologies	Dr. Vikas Nadkarni
Nasik	Spicer India	Dilip Hardikar
New Delhi	Engineers India Ltd. USAID	T.P. Rangamani, Anil Jain, Amitabha Ray

APPENDIX D

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(GOVT. OF INDIA)
PARYAVARAN BHAWAN (7th Floor)
C.G.O. COMPLEX, LODI ROAD,
NEW DELHI-110003

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APPENDIX E

CURRICULUM VITAE

AVI N. PATKAR

Education

Ph.D./1985/Chemical Engineering
M.S./1977/Chemical Engineering
B.S./1973/Chemical Engineering

Professional Registrations/Certifications

P.E./OH

Experience

Senior Staff Engineer, Radian Corporation, Cincinnati, OH, 1992-Present.
Senior Program Manager, IT Corp., 1989-1992.
Senior Process Engineer, Belcan Corp., 1985-1989.
Senior Engineer, PEI Associates (Now IT Corp.), 1977-1982.
Process Engineer, H & G Consultants, 1973-1975.

Fields of Experience

Dr. Patkar is currently a senior staff engineer in the Cincinnati office. His responsibilities include directing VOC and Air Toxics pollution control design and evaluation projects for industrial clients, and serving as senior technical support for other air pollution control projects. The areas of his expertise include:

SO_2/NO_x/Boilers:

- Dr. Patkar has designed SO_2 control systems for several industrial boilers, prepared cost estimates, and bid specifications. He has evaluated SO_2 control systems for paper and pulp mills, sulfuric acid plants, and petrochemical plants, and oil-fired boilers in enhanced oil recovery operations. the following FGD processes were evaluated: Ammonia Scrubbing. Caustic/Soda Ash Scrubbing, Citrate, Dry Scrubbing, Dual Alkali, Lime/Limestone Scrubbing, and Wellman-Lord.

- Dr. Patkar was involved in the troubleshooting of several utility FGD systems. He has presented papers on FGD technology, and co-authored the chapters on Absorbers, Pumps, and Reheaters in the manuals on Lime and Limestone FGD systems.

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- As the Task Manager on a full-scale FGD characterization study, he developed a computer program to perform a material balance around the FGD system. It included statistical analysis of the closure error.

- Dr. Patkar managed the process design of a pilot plant (20,000 scfm) for an advanced particulate, SO_x/NO_x removal process. The NO_x removal and control technology was evaluated for small boilers. He was involved in the design of a Stretford pilot plant for removal of H_2S from shale retort gas.

- For U.S. DOE, he reviewed the progress of four advanced membrane processes for SO_2/NO_x control. He also evaluated the energy conservation in refining, petrochemical, paper, and organic chemical industries.

VOC/Air Toxics

- Dr. Patkar has presented several workshops and papers on developing a compliance strategy for CAAA. The primary steps include comprehensive air emissions inventory, evaluation of pollution prevention alternatives, and evaluations of standard, novel and hybrid control systems.

- Dr. Patkar has managed several VOC control projects for industrial clients. The VOCs included ethanol, methanol, acetone, butanol, benzene, toluene, styrene, xylene, and trichlorethylene. The control systems evaluated include carbon adsorption, incineration, condensation and absorption/stripping.

- Dr. Patkar was the lead engineer on various industrial projects involving air emission inventory, VOC control system evaluation, cost estimation, bid preparation, and vendor selection. The industries serviced include appliances, printing, pharmaceuticals, and organic chemicals.

- Dr. Patkar has developed a cost model for following VOC control systems: Absorption, Adsorption, Condensation, Catalytic and Thermal Incineration. The model runs on McIntosh and performs preliminary process design of these systems. The capital and operating costs are accurate within 25%.

- Dr. Patkar managed a project on an odor control system for a pet food dryer. A pilot spray absorber using bleach solution was tested. Odor samples were taken for a panel study, a bid specification was prepared, and a vendor was selected. He has also performed troubleshooting of fume control systems for curing ovens.

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- Dr. Patkar has evaluated several H_2S control systems including caustic scrubbing, SULFEROX and LO-CAT. He has designed H_2S control systems for oil shale retort off-gas, rayon plant exhaust and municipal sludge handling plants.

- As a Lead Process Engineer, Dr. Patkar was involved in evaluating high temperature Zinc recovery processes for Electric Arc Furnace (EAF) dust. Preliminary process design was performed for 7 processes including Davy, Elkem, Scan Arc and Zia. He also was involved in upgrading the performance of dust collection systems at two foundries using EAFs.

- Dr. Patkar developed a model for absorption of acrylic VOCs in water using educator venturis. The model was computerized as a QUATTRO-PRO spread sheet. It was able to predict the effect of process parameters such as liquid pressure, L/G ratio, liquid temperature, gas residence time and recycle and bleed rates. A separate model was developed to simulate adiabatic saturation and condensation of water and VOCs from hot exhaust gas from process tanks.

Design/Process Development

- As the Lead Process Engineer, Dr. Patkar designed the pilot- and full-scale units for decontamination of metal debris at Superfund sites. The process involves washing the parts with hot detergent solution and treating the wastewater.

- Dr. was the Principal Investigator on two tasks at the U.S. EPA's Test and Evaluation facility: Vapor-Liquid Equilibrium and Wet Air Oxidation. Equilibrium constants were measured for low concentrations of 1-1 dichloroethane, nitropropane and 2-4 dichlorophenol in water. Kinetic data were collected for wet air oxidation of toluene.

- As the Lead Process Engineer, Dr. Patkar developed a process to produce a landfill polypropylene liner with nodules of LDPE laced with carbon black and an organic herbicide. The pilot plant was designed, tested, and scaled up to a 3 million lbs./year injection molding plant.

- For his Ph.D. dissertation, Dr. Patkar built a pilot plant to perform benzene and toluene chlorinations. The reactor model was developed on a PC/AT and validated experimentally. The polychlorinated hazardous aromatics can be minimized using the process modifications recommended.

- Performed process design for a fertilizer plant (600 TPD, NH_3, 1000 TPD Urea). The equipment designed includes CO_2 absorber, stripper, and heat exchangers.

Publications

"Process Modifications for Pollution Prevention in the Synthetic Organic Chemical Manufacturing Industry," A.N. Patkar and G. Henderson, Presented at the 86th Annual Air & Waste Management Association Meeting, Denver, CO, June 1993.

"Air Toxics Emission Inventory: Strategies and Database Development," J.M. Reinhold, G. Henderson, and A.N. Patkar, Presented at the 86th Annual Air & Waste Management Association Meeting, Denver, CO, June 1993.

"Novel and Hybrid Control Systems for Control of Air Toxic Emissions," A.N. Patkar and J.M. Reinhold, Presented at the 86th Annual Air & Waste Management Association Meeting, Denver, CO, June 1993.

"Evaluation of Control Systems for Recovery of Air Toxics", by A.N. Patkar and J.M. Reinhold. HAZMAT West Conference, Long Beach, CA, November 1992.

"Evaluation of Control Systems for Reduction of Air Toxic Emissions," by A.N. Patkar and J.M. Reinhold. Specialty Conference on Stratospheric Ozone, Air and Waste Management Association, Boston, MA, October 1992.

"Air Toxics Compliance - Developing a Comprehensive Plan," by A.N. Patkar et al. Presented at Clean Air Act Workshop, Manufacturers Education Council, Toledo, Ohio, September 1992.

"The utilization of Pollution Prevention Programs for Industrial Growth Planning Policies in Developing Countries," by J. Laznow and A.N. Patkar, 85th Annual Meeting, Air and Waste Management Association, Kansas City, MO, June 1992.

"Kinetics of Wet Air Oxidation of Toluene," by A.N. Patkar et al. National Meeting, Air and Waste Management Association, Kansas City, MO, June 1992.

"Hazardous Air Toxic Control Technologies," by A.N. Patkar and J. Laznow. HAZMAT World, Tower-Burner Publishing, Glen Ellyn, IL, April 1992.

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"Review of Air Toxics Control Technologies and their Application," by A.N. Patkar et al. AIChE Summer National Meeting, Pittsburgh, PA, August 1991.

"Design of Full-Scale Debris Washing System," by M.L. Taylor, M.A. Dosani and A.N. Patkar, AIChE Summer National Meeting, Pittsburgh, PA, August 1991.

"Experimental Evaluation of Selectivity in Slow Aromatic Chlorinations," by A.N. Patkar and D.B. Greenberg. Chem. Eng. Comm., vol. 57, pp. 51-66, 1987.

"An Evaluation of SO_2 Control Systems for Steam Generators in California Oilfields," by A.N. Patkar and S.P. Kothari. AIChE Symp. Series, No. 211, vol. 77, pp. 27-39, 1981.

"Treatment of Wastewater from Sodium-based FGD Systems," by A.N. Patkar and J.D. Tuttle, FGD Symposium, Houston, TX, October 1980.

PERSONAL BIO-DATA OF P. S. RAO

A. PERSONAL DETAILS:

1. Full Name: :
2. Date of birth :
3. Address: :

4. Telephone (Res):

B. EDUCATION & PROFESSIONAL QUALIFICATIONS :

1. B.E.(MECH) Bombay, 1958
2. B.E.(ELEC) Bombay, 1957
3. B.Sc.(Chem-Phy) Bombay, 1954
4. Systems Analysis & Cobol 1965
5. Computer Applications:
   Have acquired working knowledge of low level languages like Autocad (Rel.11), Lotus, and Wordstar.

6. Chartered Engineer (India) M 27919
7. Regd. Valuer (Plant & Machinery) VII-11
8. Surveyor & Loss assessor SLA 12190
9. Member, NDT soc (India)

C. TECHNICAL ASSIGNMENTS ABROAD :

1. SINGAPORE :(1987) Instrumentation Design Consultancy
2. ITALY : (1984) To assess the technical collaboration for marble processing machines in India.
3. DENMARK :(1963, 1967) Technical know-how transfer for manufacturing LP Gas Equipment in India

D. TECHNICAL CONSULTANCY ASSIGNMENTS: (1973 till date)

A.1. Industrial Engineering Applications
Productivity increase by modifications to product design production parameters like process sheets, fixtures, tool design etc.
2. Design of special purpose Machines.
3. Systems and operational procedures for Materials Management..

B. Valuation of Plant and Machinery.

E. JOB EXPERIENCE: (16 Yrs)

1. 1978 (2 Yrs) : A.P.V Equipment Co. Ltd. - Materials Manager
2. 1972 (1 Yr) : M/s W.G.Forge Ltd. - Manager (Bombshell) Manufacture of 81 mm Mortar Shells.
3. 1961 (11 Yrs): M/s Kosan Metal Products Pvt Ltd-Manager Manufacture of LP Equipment.
3. 1959 (2 Yrs) : M/s Ex-Cello India Ltd - Engineer. Manufacture of Machine Tools.

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SOME MAJOR ASSIGNMENTS

Particulars of major assignments have been summarised and the their details are listed sequentially showing

a) The name of the unit,
b) its manufacturing activity and
c) assignment undertaken

Valuation assignments have not been listed.

1. M/s FYKAYS ENGINEERING Pvt. Ltd.(1990 till date.):
   a) Instrumentation systems (Furnace temperature)
   b) Development of automatic dipping systems for molten temperature measurement,and process automation for manufacturing disposable probes.
   c) Development of computerised systems for materials management.

2. M/s FORMAC ENGINEERING Ltd.(1988):
   a) Special Purpose/Dedicated Machine Tools for Deep-hole drilling (Gun-drilling) and Precision Fine Boring Machines.
   b) Establishing machining parameters and detailed designs of:
      i) Component fixtures
      ii) Cutting tools
      iii) Specifications of spindles, and bearings,
      iv) Layout and design of machine base and positioning of slides,
      v) Design of Control circuitry for hydraulic actuation. (either through PLC or hardwired)
      vi) Component trials SQC analysis and machine acceptance.

3. M/s CONTINENTAL CASTINGS Pvt. Ltd.(1986):
   a) SG Iron Foundry
   b) Development of Management Information systems.

4. M/s ARCH ENTERPRISES.(1983):
   a) Marble processing machines
   b) Designing of complete range of machines for processing marble blocks into tiles.

5. M/s IONS.(1980):
   a) Domestic Electrical Appliances.
   b) Design of appliances.

6. M/S MURDIA & CO.:

a) General Insurance Surveyors
b) Preparation of technical reports on causes of damage to Electrical, mechanical and Chemical Equipmentfor assessing insurance loss claims.

7. M/s PRATOLINA INDUSTRIES (1976):

a) Chemical instrumentation Equipment
b) Design of import substitute instrumentation for nuclear reactor control,
c) Gauges and control valves for high pressure oil refinery service.

8. M/s KARNATAK ENGINEERING COMPANY (1974):

a) Automobile components and Machine tool accessories
b) Development of axle shafts for export. Setting up of Heattreatment shop and improvement of productivity .

9. M/s SUPNEKAR MACHINE INDUSTRIES Pvt. Ltd. (1973):

a) 81 mm Bombshells (Defence contract).
b) Improvement in production output to almost 6 times without any additional inputs.

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WEC/US-AEP

Environmental Business Exchange (EBE) Trip Reports

Febuary 22, 1995

Trip Reports as per Cooperative Agreement (CA) AEP-0015-A-00-2055-00 in Support of the U.S.-Asia Environmental Partnership

EBE ID#	EBE DATES	TITLE OF TRIP REPORT
INDI-1I	11/7-23/93	Oil Absorbent Demonstration
INDI-1K	12/6-29/93	Review of Incinerator Operations, Indian Thermal and Cyno Clean
INDI-2	4/23 - 5/6/94	Review of Pollution Prevention Control Technology in the Textile Industry
INDI-5	4/30 - 5/10/94	Clean Coal Technology Evaluation
INDI-1P (1&2)	5/94-8/94	Clean Technology for Paper Mills - Esvin - Parts 1&2
INDI-1R	6/18-30/94	Evaluation of Biological Formulations for Industrial Wastestreams Treatment (Premier Ziba)
INDI-1Q	6/18-7/1/94	Indian Boilers Manufacturers' Association Trade Mission
PHIL-8	9/27-10/6/94	Technical Assistance on H2S Gas Abatement Systems (PNOC)
HONG-1	10/23-11/9/94	Coleman Energy and Environmental Systems Technology Transfer
KORE-1	12/9-22/93	Fuel Gas Desulfurization Technology Assessment (KEPCO)
INDI-1L	1/17-2/23/94	Corporate Environmental Mission (IT Corporation Exchange)
INDI-4	3/11-30/94	Evaluation of CS_2 Recovery in Rayon Mills

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