



**Center of Excellence for  
Process Integration**

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## ملخص

يعتبر ترشيد المياه وترشيد الطاقة وحماية البيئة من المسائل التي اصبحت لها اهمية كبرى فى الصناعات الكيماوية والبتروكيماوية على مستوى العالم وتحديداً فى المملكة العربية السعودية. إن قطاع الصناعات الكيماوية والبتروكيماوية بالمملكة يعتبر من القطاعات المهمة والذي يحتوى على صناعات متعددة تعتبر الاكثر فى استهلاك المياه والطاقة وكذلك فى طرح المخلفات والملوثات البيئية. ومما يزيد من هذا التحدى فى المملكة ندرة المياه وارتفاع تكلفة اعادة استخدامها. إن ترشيد استهلاك المياه والطاقة باستخدام الطرق الهندسية الحديثة (تكامل العمليات الصناعية) يعتبر من الطرق الناجحة لتخفيض التكلفة التشغيلية للقطاع الصناعى وبالتالي زيادة ربحيته، علاوة على إيجاد الطرق الفعالة لحماية البيئة. وبالإضافة الى أهمية المسائل الثلاثة المذكورة فان هناك ترابطاً بينها. ذلك ان الملوثات الغازية فى أي محطة صناعية تعتبر علامة على كفاءة استهلاك الطاقة بحيث ان ترشيد استهلاك الطاقة يؤدى غالباً الى الحد من هذه الملوثات كما ان ترشيد استهلاك المياه يخفض من كميات مخلفات المياه الصناعية. ولقد ظهرت ابحاث و طرق متعددة للتعامل مع المسائل الثلاثة المذكورة الا انه فى العقد الاخير تم تطوير تقنية تكامل العمليات كوسيلة فعالة للتعامل مع المسائل الثلاثة بطريقة متكاملة. ان تقنية تكامل العمليات تعبر عن مجموعة من الوسائل البيانية والنماذج الرياضية والحاسوبية التى تتيح داخل أي محطة صناعية الاستخدام الامثل للموارد الخام (و خاصة المياه) و موارد الطاقة مع مراعاة عدم تجاوز معايير البيئة الخاصة بصرف المخلفات سواء الغازية او المائية او الصلبة. ولقد لاقت تقنية تكامل العمليات نجاحاً باهراً وتم انشاء مراكز ابحاث متعددة فى عدد من الجامعات لتطوير وتطبيق هذه التقنيات بالتعاون مع الشركات الصناعية وكمثال لهذه المراكز هناك مركز تكامل العمليات بجامعة مانشستر بالمملكة المتحدة ومركز تقنية تكامل العمليات والاغشية بجامعة نيو هامبشير بالولايات المتحدة الامريكية.

ان الهدف من انشاء مركز تكامل العمليات فى جامعة الملك سعود هو الاقتداء بتجارب الجامعات الاخرى خاصة وان القطاع الكيماوى والبتروكيماوى بالمملكة يضاهاى فى اهميته القطاعات الموجودة فى الدول الصناعية الكبرى ويعانى القطاع من نفس التحديات فيما يخص ترشيد المياه والطاقة والتحكم فى التلوث.

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## **Abstract**

Water Conservation, Energy Efficiency and Environmental Protection are three areas that are becoming increasingly important in the chemical and petrochemical industries worldwide. These three issues are particularly important to the kingdom, for the following reasons: Process industries are the most important manufacturing facilities in the Kingdom of Saudi Arabia. Water is used extensively in petroleum, chemical and petrochemical processes. However fresh water suitable for these industrial uses is becoming an increasingly expensive commodity and the costs of cleaning industrial process waters to a level adequate for discharge is also increasing. Second, the chemical and petrochemical sector in the kingdom includes some of most energy extensive industries. The energy cost represents a sizable part of the production cost of these industries; therefore the minimization of the energy cost would increase the profitability. Finally the chemical and petrochemical sector is the greatest pollutant of the industrial sector. Environmental protection is becoming an important issue and laws setting guidelines for air and ground discharge are being put in place in the kingdom by the environmental authority. The three issues of water conservation, energy utilization and environmental protection are not only important but are also interrelated in chemical and petrochemical industry. Gaseous emissions are generally an indication of the energy efficiency of the plant, since a reduction in energy consumption will reduce the environmental impacts of these gaseous emissions. Water discharges are also indications of water utilization in the plant. Minimizing fresh water used through reuse/recycle/regeneration would ultimately lead to smaller wastewater discharge.

There are a variety of tools that have been developed in the literature and practiced by the industry worldwide to deal with the three issues of water conservation, energy utilization and environmental protection. In the last decade a new unified paradigm, Process Integration (PI), has emerged that allows dealing with the three issues in a unified approach. Process Integration (PI) refers to the application of systematic methodologies that facilitate the selection and/or modification of processing steps, and of interconnections and interactions within the process, with the goal of minimizing resource use and pollutant emission. PI techniques can be used for grass root designs, or to retrofit existing installations, in order to ensure that energy, water, and raw materials are used optimally. Because of the importance of the subject, a number of research centers worldwide have been established to carry out both research and applications for these techniques. These include the Process Integration Center in University of Manchester, UK and the Center for Process Integration & Membrane Technology in the University of New Hampshire, USA.

The main objective of this proposed center in the King Saud University is to carry out practical applications of the process integration (PI) tools to the existing chemical and petrochemical industries in the kingdom in the goal of minimizing water and energy use. This will be accompanied by a review of existing air and waste water discharges policies practiced by different companies within the sector and the proposal, if necessary, of new guidelines based on international criteria. The general methodology to be practiced by the center, to achieve its objectives, is to first carry out a preliminary assessment of the current situation of the chemical and petrochemical sector in the kingdom in terms of resources usage such as water & energy as well as the emissions from such industries. This would facilitate the classification of the sector in a number of subsectors, based

on their nature and based on their water and energy utilization and the types of emissions. The methodology then consists in carrying out technical studies on each subsector, using PI tools, to identify potentials for water & energy savings, to reduce the emissions, and to propose practical measures to implement these changes. The methodology of the proposed center also relies on close cooperation with the chemical and petrochemical sector in the kingdom to provide flow diagrams of process, data, current practices in water & energy efficiency and the existing guidelines used for gaseous and wastewater discharge.

# 1. Introduction

## 1.1 Motivations for process integration

Process industries are the most important manufacturing facilities in the Kingdom of Saudi Arabia. They span a wide range of industries including chemical, petroleum, gas, petrochemical, pharmaceutical, food, microelectronics, metal, etc. They are characterized by the enormous usage of resources whether it may be natural or chemical. Minimization of capital investment, reduction in raw material cost, energy usage minimization, increase in process flexibility and reduction in inventory, greater emphasis on process safety, quality control, and better environmental performance are the seven themes identified by Keller and Bryan (2000) as the key drivers for process-engineering research, development, and changes in the primary chemical process industries. The question is how? What are the challenges, required methodologies, and enabling tools needed to carry out their responsibilities?

A chemical process is an integrated system of interconnected units and streams. A thorough understanding of process problems should not be narrowed to symptoms of the problems but should identify the root causes of these problems through treating the process as a whole. Moreover, effective improvement and synthesis of the process must account for this integrated nature. Therefore, integration of process resources is a critical element in designing and operating cost-effective and sustainable processes. *“Process integration is a holistic approach to process design, retrofitting, and operation which emphasizes the unity of the process”* (El-Halwagi, 1997).

In light of the strong interaction among process units, resources, streams, and objectives, process integration offers a unique framework for fundamentally understanding the global insights of the process, methodically determining its attainable performance targets, and systematically making decisions leading to the realization of these targets. Process integration involves the following activities:

- **Task Identification:** The first step in synthesis is to explicitly express the goal to be achieved and describe it as an *actionable* task. The actionable task should be defined in such a way so as to capture the essence of the original goal. For instance, pollutant diminution may be described as a task to reach a specific composition or certain properties of the effluent streams. In characterizing the task, the salient information and constraints are to be described properly. Additionally, the task should be characterized by some quantifiable metrics. For instance, the task may be quantified with an extreme performance (e.g., minimum wastewater discharge), a specific value (e.g., 50% reduction in wastewater), or as a multivariable function (e.g., relationship between extent of wastewater reduction and pollutant content).
- **Targeting:** The concept of targeting is one of the most powerful contributions of process integration. Targeting refers to the identification of performance benchmarks ahead of detailed design. These targets can be rigorously determined without conjecturing how the implementation scheme looks like. Targeting determines how far process performance can be pushed and sheds useful insights on the exact potential and realizable opportunities for the process. Targeting is useful to benchmark the current versus the ultimate performance.
- **Generation of Alternatives (Synthesis):** Given the enormous number of possible solutions to reach the target (or the defined task), it is

necessary to use a framework that is rich enough to embed all configurations of interest and represent alternatives that aid in answering questions such as: How should streams be rerouted? What are the needed transformations (e.g. separation, reaction, heating, etc.)? For example, should we use separations to clean up wastewater for reuse? To remove what? How much? From which streams? What technologies should be employed? For instance, should we use extraction, stripping, ion exchange, or a combination? Where should they be used? Which solvents? What type of columns? Should we change operating conditions of some units? Which units and which operating conditions? The right level of representation for generating alternatives is critically needed to capture the appropriate design space. Westerberg (2004) underscores this point by stating that “*It is crucial to get the representation right. The right representation can enhance insights. It can aid innovation.*”

- **Selection of Alternative(s) (Synthesis):** Once the search space has been generated to embed the appropriate alternatives, it is necessary to extract the optimum solution from among the possible alternatives. This step is typically guided by some performance metrics that assist in ranking and selecting the optimum alternative. Graphical, algebraic, and mathematical optimization techniques may be used to select the optimum alternative(s). It is worth noting that the generation and selection of alternatives are *process synthesis* activities.
- **Analysis of Selected Alternative(s):** Process analysis techniques can be employed to evaluate the selected alternative. This evaluation may include prediction of performance, techno-economic assessment, safety review, environmental impact assessment, etc.

## 1.2 Categories of process integration

Over the past two decades, numerous contributions have been made in the field of process integration. These contributions may be classified in different ways. One method of classification is based on the two main commodities consumed and processed in a typical facility: energy and mass. Therefore, from the perspective of resource integration, process integration may be classified into energy integration, mass integration, and property integration. *Energy integration* is a systematic methodology that provides a fundamental understanding of energy utilization within the process and employs this understanding in identifying energy targets and optimizing heat-recovery and energy-utility systems. On the other hand, *mass integration* is a systematic methodology that provides a fundamental understanding of the global flow of mass within the process and employs this understanding in identifying performance targets and optimizing the generation and routing of species throughout the process. *Property Integration* is a functionality-based, holistic approach to the allocation and manipulation of streams and processing units for non chemo-centric processes, which is based on the tracking, adjustment, assignment, and matching of functionalities throughout the process.

## 1.3 Tools of process integration

The process integration includes three types of techniques: Graphical techniques, algebraic techniques, and mathematical programming methods. Pinch analysis, for instance, is graphical and algebraic technique for investigating the energy flows in a given process, and for quantifying the minimum practical utility demands for process heating and cooling. The latter information is very useful, as it allow a comparison of the actual energy consumption with a minimum, and to identify the real potential for improvement. Mathematical programming

methods are also tools that belong to process integration. In the mathematical programming method, different mathematical models are used to analyze and optimize the system. Mathematical programming methods provide a methodology for determining optimal strategies to minimize the energy & water utilization while obeying the strict environmental discharge criteria. Different algorithms for solving the optimization problem are used depending on the type of problem. These may include linear programming (LP). A problem using both continuous and discrete variables, i.e. binary variables, to represent the system requires mixed integer linear programming (MILP). The use of discrete variables makes the modeling more flexible. However, the problem and the technique to solve the problem increase in complexity. Non-linear programming (NLP) and mixed integer non-linear programming (MINLP) increase the flexibility in modeling even more. The complexity on the other hand also increases.

## 2. Organization of the Center

- Director of the center: Dr. Abdulaziz Almutlaq: Assistant professor at the chemical engineering department, King Saud University. Dr. Almutlaq Ph.D dissertation was on Process Integration (PI), under the supervision of Prof. El-Halwagi who is a worldwide leader in the field. Dr. Almutlaq has published papers on the use of integrated graphical and mathematical programming PI tools for the resources minimization and pollution control in the process industries. (Please Check his CV).
- Vice-Director: Dr. Abdulrahman Al-Rabiah: Assistant professor at the chemical engineering department, King Saud University. Dr. Al-Rabiah dissertation was on utilizing new technologies for ethylene production, under the supervision of Prof. Klaus D. Timmerhaus. Pinch Analysis was used extensively in his Ph.D. work to integrate the entire ethylene plant. Dr. Al-Rabiah has published papers in different journals and proceedings. His research is mainly in the area of process integration. (Please check his CV).
- Dr. Abdelhamid Ajbar: Professor at the chemical engineering department of the King Saud University. His interest is in the mathematical analysis of biological systems for the treatment of wastewater in which he published numerous articles (Please check his CV).

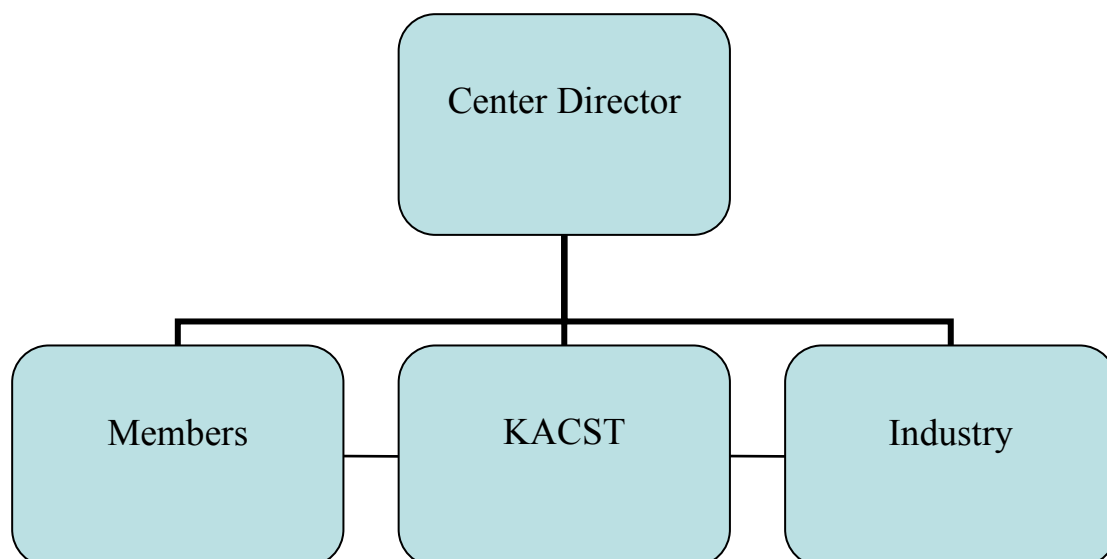
### **3. Permanent Members of the Center**

- Dr. Abdulaziz Almutlaq (Mentioned in the previous paragraph)
- Dr. Abdulrahman Rabiah (Mentioned in the previous paragraph)
- Dr. Abdelhamid Ajbar (Mentioned in the previous paragraph)
- Dr. Kamil Wagialla: Professor at the department of chemical engineering, King Saud University. His interest is in mathematical modelling and simulation of reactor engineering systems. He has has taught several courses in the undergrauate and postgraduate level in process synthesis and integration. He has 5 years experience in the field of techno-economic evaluation of chemical industires at “Gulf Organization of Industrial Consulting, at Doha” and “Saudi House for industrial consultations, at Riyadh”.
- Dr. Ahmed Aidid: Research Center of the College of engineering at King Saud University. Dr. Aidid has been an active member of the research center and he took part in many research projects carried out in the different departments of the college of engineering. Dr. Aidid responsibilities in the center will include the participation in the analysis of data received from the diverse chemical and petrochemical industries, flow sheet design, mathematical modeling and coding .

- Assistant in administration. A person, to be chosen later, will be needed for secretarial job including typing and correspondences.

## 4. Consultants & Cooperating Members

- Dr. M. Elhalwagi: Professor at Chemical Engineering Department, Texas, A & M, USA. Dr. Alhalwagi is world leader in Process Integration and he has trained dozens of Ph.D students in the field. He has numerous papers in the field and he has also solid practical experience dealing with the applications of PI tools in the chemical and petrochemical sector.
- Dr. M. Al-Otaibi: Saudi Arabian Basic Industry Corporation (SABIC). He is currently a member of the research and technology division of SABIC. Dr. Al-Otaibi Ph.D dissertation was on Process Integration (PI), under the supervision of Prof. El-Halwagi. Dr. Al-Otaibi has published papers on the interval based process yield enhancement. (Please Check his CV).
- Jimmy Comana: Arabia American Oil Company (ARAMCO). He is a specialist in energy integration.



## 5. Center Objectives and Outputs

### 5.1 Importance of the Center

Conservation of resources, efficient utilization of energy, and pollution control are important issues facing the chemical and petrochemical industry in the kingdom. This expanding important sector in the kingdom is known to be a huge consumer of water resources and energy and also a great source for air and water pollution. The three issues are closely related in the sector. Air emissions are generally an indication of the energy efficiency of the plant, since a reduction in energy consumption will reduce the environmental impacts of these gaseous emissions. Water discharges are also indications of water utilization in the plant. Minimizing fresh water used through reuse/recycle/regeneration would lead necessarily to smaller wastewater discharge. The

Process Integration Center (PIC) will adopt and use the powerful existing PI tools (either graphical or mathematical) to tackle the three issues in a unified way. This includes the assessment of current status in water resources management, energy utilization and the current guidelines for air and wastewater discharge, the identification of potential water and energy savings in the sector, and the synthesis of environment friendly optimal solutions for water and energy utilization.

## **5.2 General Objective of the center**

The general objective of the proposed center is to implement the Process Integration (PI) tools to the existing chemical and petrochemical sector in the kingdom in order to achieve efficient use of raw materials (with emphasis on water), energy efficiency and clean environment.

## **5.3 Specific objectives:**

- Classification of the chemical and petrochemical sector in the kingdom into subsectors, based on their nature, water and energy consumption and on their discharge to the environment..
- Assessment of the current situation in each subsector in terms of current water management policy, energy efficiency and pollution control.
- Application of Process Integration tools to real plant cases from each subsector. This includes:
  - Development of a systematic approach based on the use of graphical and/or algebraic and mathematical programming methods for the design of optimal (i.e. cost-effective) recycle/reuse/regeneration wastewater treatment

systems while the overall process receives water of adequate quantity.

- Identification of potentials for energy savings through the use of pinch technology and proposal for energy savings methods.

- Proposal of guidelines to meet international standards for discharge. These criteria will be proposed after surveying the type and quality of pollutants in the subsector and the available or potential treatment technologies, and also after careful study of the current employed standards in the subsector.

#### **5.4 Center Deliverables**

The following outputs will be generated from the center:

- A database showing a classification of the chemical and petrochemical sector in the kingdom into subsectors indicating the quantity and water usage, the energy consumption and the quantities and type of pollutants for each subsector.
- Results from real case plants for each subsector identifying potentials for water, energy savings and pollutions control.
- Results on applications of process synthesis tools on real case plants showing strategies for water reuse/recycle/regeneration, energy savings and pollutants discharge.
- Setting up criteria for wastewater discharge. This will be carried out based on the database developed for the type of contaminants, their concentrations as well as based on the potential reductions in the pollutants concentrations as result of

the proposed treatment strategies. Based on survey of the currently used and international industrial standards, a number of guidelines will be proposed for the criteria for water discharge.

### **5.5 Projects time frame**

The center will start its activities as soon as it is approved. The duration of the center activities will last five years. The specific activities to be carried out will be covered in the next paragraph.

## **6. Center Management Plan**

The following is a description of the tasks to be carried out by the Center members.

### **6.1 Permanent Centre Members**

- Dr. Abdulaziz Almutlaq is the director of the centre. He will be responsible for the management of the center. This includes the supervision of the timetable schedules, the assignment and the coordination between the team members and the contact with external partners including KACST, companies and consultants to the centre. Dr. Almutlaq will also be particularly responsible for the selection of Process Integration tools for the water minimization part of the projects.
- Dr. Abdelrahman Al-Rabiah is the Vice director of the centre. He will be particularly responsible for the energy efficiency

part of the projects. He will identify the energy savings opportunities in the projects and propose appropriate energy savings measures.

- Dr. A. Ajbar will be responsible for the selection of appropriate software and the implementation of the optimization methods. He will be responsible for the formulation of the questionnaires to be sent to the different chemical and petrochemical sector in the kingdom. He will also be responsible for the review of current guidelines for discharge as well as the proposal of new guidelines that meet international standards.
- Dr Kamil Wagialla will be responsible for the economic evaluations in relation to the optimization and projects' feasibilities.
- Dr. Ahmed Aidid will be responsible for the coding and the execution of the different computer algorithms used throughout the projects.

The first four team members will take part together in reports writing, projects evaluation, as well as elaboration on final results and recommendations.

## **6.2 Consultants to the Centre**

- Dr. M. El-halwagi is the first consultant to the centre. His wide practical experience and authority in the field of Process Integration will make him very valuable to the centre. His primary tasks is to assist the center in his experience in selecting the best methodology to deal with each of the subsector of the chemical & petrochemical sector in the kingdom. For each subsector and real case

application he will assist the team in developing a methodology for the application of PI tools.

- Dr. M. Alotaibi is the second consultant to the center. His position in SABIC and his expertise in Process Integration will be valuable in setting up cooperation with the SABIC operated plants.
- Jimmy Comana .....

### **6.3 Strategy of Execution**

The methodology of the execution of the activities of centre tasks will rely on the following points:

- Assessment of the current situation of water use, energy efficiency and pollution control in the chemical and petrochemical sector in the kingdom. A survey of this sector will be carried out using questionnaires, personal contacts and visits. This will help in the classification of the sector into subsectors of similar trends and in identifying the current status of water management, energy efficiency and discharge policies and guidelines. It will also help in understanding the motivation/obstacles for better water, energy and pollution control strategies.
- Development and use of computer codes: Some of these codes are based on generic mathematical programming and algebraic methods for the design of optimal wastewater reuse/regeneration/recycle strategies. Some of these codes are based on the use of graphical methods for the synthesis of optimum heat networks. Other codes will be based on using steady state mathematical models of the process and their

simulation using some commercial packages. These programs will make use of existing software for optimization such as LINGO and WATER and also simulation packages such as Aspen Plus, Aspen Pinch, ChemCad and SuperPro.

- Implementation of these techniques on real cases. For each of the subsector identified in previous steps, real cases of plants will be studied. This involves detail analysis of the water and energy savings opportunities in these plants and the extrapolation to the findings to the subsector. The studied cases will help in validating the above procedures and also in reevaluating the assumptions made. It also helps in identifying the constraints for a realistic implementation of the above solutions.
- Setting up criteria for discharge: This will be carried out based on the database developed for the type of contaminants, their concentrations as well as based on the potential reductions in the pollutants concentrations as result of the proposed treatment strategies. Based on survey of the currently used and international industrial standards, a number of guidelines will be proposed for the criteria for air and ground discharge.
- Developing power cogeneration strategies and optimize utility usage through energy integration with emphasis on combined heat and power optimization.

#### **6.4 Selected Topics to be studied in the Center**

- Classification of the chemical and petrochemical sector in the kingdom. Because the chemical and petrochemical sector in the

kingdom is a large sector and consists of a variety of activities the first step will be to classify the sector into subsectors using the water, energy use and discharge policies as criteria for the selection. This will help in identifying the industrial activities that are consuming large quantities of water or energy or discharging large quantities of pollutants to the air or ground.

- Application of process integration tools to selected subsectors. The selection of which subsector to start working with depends obviously on the results of the first step (classification of the sector). However we know that some subsectors are perfect candidates for the study. This include the following subsectors:
  - Petrochemical industries: petrochemical facilities are a large consumer of raw material and creator of pollution, the inefficient usage of fresh material ultimately leads to a greater pollutant effluents.
  - Oil refineries. The refining of oil is an important petrochemical activity carried out mainly by ARAMCO. The refineries are large water and energy consumers and also they discharge large amounts of pollutants to air and ground.
  - Iron and steel industry. The reduction of iron and the production of steel are known to be an energy extensive industry and also consume large amounts of water. The gaseous emissions are also important. The operation of the iron and steel is carried out in the kingdom by SABIC affiliate Hadeed.
  - Olefins production. The production of ethylene and propylene is an important industrial activity in the kingdom. It involves a large number of separations carried out in distillation columns. Consequently these operations are

energy consuming. There are also large amounts of fresh water needed for the operations. SABIC operates a number of plants in the kingdom for olefins production.

- Cement industries: Cement industries are important industrial activities in the kingdom, carried out by a number of companies. The cement sector is known to be a large consumer of energy and also a large pollutant.
- Other sectors will be identified after the survey of the entire chemical and petrochemical sector is carried out.

### **6.5 Obstacles that may be faced and role of KACST**

The center can not achieve its objectives without close cooperation with the different industries in the kingdom. The vision of the center is to establish partnership with the major companies in the kingdom in order to acquire data and all other relevant information. In this regard the team will rely on its personal contacts. However KACST help will be valuable in facilitating the contact with the industry and providing any information that may be useful to the centre.

## **7. Planned Activities of the Centre In the Next Five Years**

- 1428/1429: A general survey of the chemical and petrochemical sector in the kingdom and the classification of the sector into various subsectors in terms of water and energy use and the discharge to environment. Assessment of the current policies of water, energy efficiency and pollution control in the subsectors.
- 1429/1430: Detailed study of a specific subsector (Oil refinery, Iron & steel industry, cement industry, Dairy industry....). The study will be carried out on selected real plants that represent the subsector. The study covers the identification of the potentials for water and energy savings and implementing of Process Integration (PI) tools for the development of optimal solutions for the water and energy savings and for pollution control. In addition the study will set up guidelines, if necessary, for the discharge of pollutants characteristics of the subsector.
- 1430/1431: A similar study will be carried out on an other subsector
- 1431/1432: A similar study will be carried out on an other subsector
- 1432/1433: A similar study will be carried out on an other subsector

## **8. Preliminary Vision for the Objectives to be Established in the Next Five Years**

The following specific objectives will be carried out:

- Assessment of the current situation of water use, energy efficiency and pollution control in the chemical and petrochemical sector in the kingdom. A survey of this sector will be carried out using questionnaires, personal contacts and visits. This will help in the classification of the sector into subsectors of similar trends and in identifying the current status of water management, energy efficiency and discharge policies and guidelines. It will also help in understanding the motivation/obstacles for better water, energy and pollution control strategies.
- Detailed case studies for a number of important subsectors. This may include oil refineries, olefins plants, cement plants, iron & steel industry and food industry...etc. The study covers the identification of the potentials for water and energy savings and implementing of Process Integration tools for the development of optimal solutions for the water and energy savings and for pollution control. In addition the study will set up guidelines, if necessary, for the discharge of pollutants characteristics of the subsector.

## **9. Assessment Tools**

The center will measure the success of its mission through the following indicators:

- Periodical reports for each phase to be submitted and discussed with KACST and the companies that are part of the projects.
- Final reports to be submitted and discussed with KACST and the relevant companies.
- Publications of conference or journal papers presenting the results of the projects carried out by the center.
- Annual seminar and courses to be held in order to enlighten participating entities on the field of process integration and its advances.

**10. Financial and Manpower Requirements for Center  
(Please check the tables)**

## Form for Project Costs أنموذج تكاليف المشروع

إجمالي الخطة (Total)	المخصصات السنوية للخطة Annual Funds					الباب (Section)	نوع الإنفاق
	1433/1432 هـ	1432/1431 هـ	1431/1430 هـ	1430/1429 هـ	1429/1428 هـ		
200,000			50,000		150,000		1- أجهزة ومعدات (Equipments)
250,000	50,000	50,000	50,000	50,000	50,000		2- دراسة استشارية (Consultancy studies)
1,000,000	200,000	200,000	200,000	200,000	200,000		3- خبراء (Consultants)
1,200,000	240,000	240,000	240,000	240,000	240,000		4- مكافآت (Compensation)
300,000	60,000	60,000	60,000	60,000	60,000		5- قوى بشرية (Manpower)
							6- تدريب (Training)
							7- تشغيل (Operations)
							8- إنشاء (Building)
							9- أخرى (Others)
2,950,000	550,000	550,000	600,000	550,000	700,000		<b>الإجمالي</b>

أنموذج الاحتياجات من القوى العاملة على بنود التشغيل والصيانة  
Forms for Requirements for manpower

تحت التنفيذ/جديد <input checked="" type="checkbox"/> <input type="checkbox"/>	King Saud University جامعة الملك سعود	الجهة
	Process Integration Center مركز تميز لتكامل العمليات	اسم المشروع
	Riyadh الرياض	المدينة

المجموع بنهاية الخطة (Total)	المطلوب إضافته في كل سنة من سنوات الخطة Required Addition Each Year					نوع الوظائف Type of Jobs	
	1433/1432هـ	1432/1431هـ	1431/1430هـ	1430/1429هـ	1429/1428هـ		
						أستاذ (Professor) مشارك (Assoc.) مساعد (Assist.)	كادر أعضاء هيئة التدريس (faculty Member)
						محاضر (Lecturer)	
						معيد (Teaching assistant)	
						المجموع الفرعي (Subtotal)	
1	1	1	1	1	1	إداريون (Administrators)	الكادر الوظيفي (Admin. member)
1	1	1	1	1	1	مهنيون (Professionals)	
						فنيون (Technicians)	
2	2	2	2	2	2	المجموع الفرعي (Subtotal)	
						<b>الإجمالي</b>	

## 11. Utilization of the expected results

A number of parties will benefit from the activities of the centre. As we mentioned before the vision of the center is to establish partnership with the chemical and petrochemical sector in the kingdom to implement the tools for Process Integration for water, energy savings and pollution control. The lists of parties that may benefit from the activities of the centre include:

- Authorities supervising the water sector such as the ministry of water and electricity and the saline water corporation.
- Authorities dealing with pollution control and policies: The general presidency for weather service and environmental protection.
- Many sub-sectors in the chemical and petrochemical sector. This include:
  - Aramco operated oil refineries
  - SABIC operated iron and steel plants
  - SABIC operated olefins plants
  - Cements industries
  - Dairy industries....

## **12. Role of KACST and Other Parties In the Activities of the Center**

As we have mentioned before the vision of the center is to form a partnership with the different companies in the chemical and petrochemical sector. The center proposes the following roles for both KACST and the companies dealing with the centre:

- For KACST: The center proposes that KACST has a supervising role similar to the role it carries in sponsoring research projects. Moreover KACST would cooperate with the center in establishing contacts with the companies and acquiring data and relevant information from them.
- For companies: The companies will be directly involved with the center, in terms of discussing methodologies for study and results obtained by the center. The center will submit periodical and final reports to both KACST and the companies. The reports will be reviewed and discussed by the companies and implementation strategies for these results will also be discussed with these companies.

## **13. CVs for Centre Members and Consultants**

## **Dr. Abdulaziz Almutlaq**

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PO Box 800, Riyadh 11421  
Saudi Arabia

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FAX: (01) 467-8770  
e-mail: mutlaq@ksu.edu.sa

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### **EDUCATION**

**Ph.D.** (Chem. Eng.), 2005, Texas A&M University, USA

Dissertation: " *Algebraic Approaches to Resource conservation via Process Integration*"

**MSc.** (Chem. Eng.), 1998, King Saud University, Saudi Arabia

**BSc.** (Chem. Eng.), 1987, King Saud University, Saudi Arabia

### **EXPERIENCE**

**Assistant Professor**, 2005-present

Dept. of Chemical Engineering, King Saud University, Riyadh, Saudi Arabia.

Lecturer, 1998 – 2001

Dept. of Chemical Engineering, King Saud University, Riyadh, Saudi Arabia.

Teaching Assistant, 1987-1989

Dept. of Chemical Engineering, King Saud University, Riyadh, Saudi Arabia.

**Co-op at ARAMCO May –July, 1984-1986**

### **Attended Courses**

**Basic GAMS Class**

**Instructor: Bruce McCarl**

**College Station, Texas, May 2003**

Practical HEN Retrofit Design Methods

Instructor: J. T. Polley

Dahran, Dec 3-14, 2005

## **Current Interest:**

- Process Intensification through Process Integration
- Industrial Waste Water Management.
- Simulation and Modeling of Direct Reduction of Iron.

## **Courses Taught in Process Integration**

- CHE 422 Selected Topics devoted to “Process Integration”
- CHE 421 Plant Design and Economics

## **Sponsored Research Projects**

- *Simulation and modeling of Hadeed’s direct reduction of iron.*

Principal Investigators: K. Al-Humaizi, M. Solieman, S. Al-Zahrani, and A. Almutlaq  
Sponsored by Sabic Hadeed, Sabic, K.S.A.  
Status: Report ongoing

- *Wastewater Management in the Petroleum Refineries in the Kingdom.*

Principal Investigators: A. Almutlaq, I. Al-Mutaz, and A. Ajbar  
Sponsored by KACST  
Status: ongoing

## **Papers Published in International Research Periodicals**

1. Almutlaq, A. and El-Halwagi, M.M. “An algebraic targeting approach to resource conservation via material recycle/reuse”, *Int. J. of Environ. and Pollution (IJEP)*, Vol. 29, 4-18 (2007)
2. Almutlaq, A., Kazantzi, V. and El-Halwagi, M.M. 2005. “An algebraic approach to targeting waste discharge and impure-fresh usage via material recycle/reuse networks”, *J. Clean Technologies & Env. Policy*, 7(4): 294-305.

## **ABDULRAHMAN A. AL-RABIAH**

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---

### **EDUCATION**

**Ph.D.** (Chem. Eng.), 2001, University of Colorado, Boulder, USA

Dissertation: " **Design and Optimization of Ethylene Production Utilizing New Technologies** "

Supervision: Prof. Klaus D. Timmerhaus and Prof. Richard D. Noble  
GPA: (3.96 / 4.0)

**M.Sc.** (Chem. Eng.), 1992, University of Colorado, Boulder, USA  
Awarded **Ambassador's Honor Award**

**B.Sc.** (Chem. Eng.), 1990, King Saud University, Riyadh, Saudi Arabia  
Awarded **First Class Honor**

### **ACADEMIC EXPERIENCE**

**Assistant Professor**, 2001– Present

Dept. of Chemical Engineering, King Saud University, Riyadh, Saudi Arabia.

**Teaching Assistant**, 1990-1991

Dept. of Chemical Engineering, King Saud University, Riyadh, Saudi Arabia.

### **INDUSTRIAL EXPERIENCE**

**Training at Al Jubail Desalination Plant, May 1989-August-1989**

Developed a thorough working knowledge of all processes and aspects of the world's largest desalination plant.

**CONSULTATION** **Global ChemTech Company**, 2005- Present

## **RESEARCH INTERESTS**

- 1- Process Synthesis.
- 2- Simulation, Modeling and Optimization.
- 3- Hybrid Systems.
- 4- Heat Integration Using Pinch Analysis.
- 5- Membrane Reactors.
- 6- Facilitated Transport Membranes.
- 7- Fine and Spatiality Chemicals.
- 8- Economic Evaluation and Profitability Analysis.

## **MEDIA**

- “Distillation Joined with Facilitated Transport,” Membrane & Separation Technology News, Vol. 17, No. 8, 7-8, BCC, Inc. Publication, April 1999.
- “Meeting News: By John Lewis,” Membrane Quarterly, Vol. 14, No. 3, 26, NAMS, July 1999.

## **PROFESSIONAL AFFILIATIONS**

- American Institute of Chemical Engineers (*AIChE*), Member
- North American Membrane Society (*NAMS*), Member

## **HONORS AND AWARDS**

- Ambassador’s Honor Award (University of Colorado, Boulder)
- First Class Honor (King Saud University)

## **SPONSORED RESEARCH PROJECTS**

- ***Utilization of a Hybrid Membrane System for Propane/ Propylene Separation in Ethylene plants***

Principal Investigator: Abdulrahman A. Al-Rabiah

Sponsored by ***Research Center, College of Engineering, King Saud University***

Status: ***Completed***

- ***Membrane Technology for Hydrogen Separation in Ethylene Plants***

Principal Investigator: Abdulrahman A. Al-Rabiah  
Sponsored by **SABIC**  
Status: **Completed**

- ***Production of Alkenyl Succinic Anhydride in Saudi Arabia Using C12 Alpha Olefins. (Projects No. 151).***

Principal Investigator: Abdulrahman A. Al-Rabiah  
Sponsored by **SABIC through King Abdullah Institute for Research & Consulting**  
Status: **Completed**

- ***Production of Alkenyl Succinic Anhydride in Saudi Arabia Using C14-C18 Alpha Olefins. (Projects No. 152).***

Principal Investigator: Abdulrahman A. Al-Rabiah  
Sponsored by **SABIC through King Abdullah Institute for Research & Consulting**  
Status: **Completed**

- ***Production of ADA in Saudi Arabia Using C12 and C14-C18 Alpha Olefins. (Projects No. 153 and 154).***

Principal Investigators: Abdulrahman A. Al-Rabiah, Kamil Wagjallah  
Sponsored by **SABIC through King Abdullah Institute for Research & Consulting**  
Status: **Completed**

- ***Production of Plasticizer Alcohols in Saudi Arabia from Linear Alpha Olefins (LAO) Project No. 155***

Principal Investigators: Abdulrahman A. Al-Rabiah, Kamil Wagjallah  
Sponsored by **SABIC through King Abdullah Institute for Research & Consulting**  
Status: **Completed**

- ***Production of Detergent Alcohols in Saudi Arabia from Linear Alpha Olefins (LAO) Project No. 156***

Principal Investigator: Abdulrahman A. Al-Rabiah  
Sponsored by **SABIC through King Abdullah Institute for Research & Consulting**  
Status: **Completed**

- ***Performance of Polymer Modified Bitumen (PMB) Based on Local Bituminous Materials***

Principal Investigator: Abdulrahman A. Al-Rabiah  
Sponsored by **Transport Ministry through King Abdullah Institute for Research & Consulting**  
Status: **Ongoing**

- **Down Stream Products from Polycarbonate Resin**

Principal Investigator: Abdulrahman A. Al-Rabiah  
Sponsored by **SABIC through King Abdullah Institute for Research & Consulting**  
Status: **Ongoing**

### **COURSES TAUGHT (Related to Process Integration)**

- CHE 551 Advanced Topics in Chemical Engineering “Energy Optimization Using Pinch Analysis”.
- CHE 321 Computer Aided Design for Chemical Processes.

### **INSTITUTIONAL SERVICE**

- Computer Lab Committee, Head, 2002-2005
- Undergraduate Projects Committee, Head, 2003-present
- Student Affairs Committee of Engineering College, 2003-2006
- Laboratories and Experimental Equipment Committee, Member 2006-present

### **SELECTED PUBLICATIONS AND PRESENTATIONS**

1. Al-Rabiah and A. Ajbar, "Study of the Operability of a Continuous Bioreactor for the Pre-Fermentation of Cheese" *Engineering in Life Sciences* (in Press).
2. Abashar, M.E.E.; Al-Rabiah, A.A. "Production of Ethylene and Cyclohexane in a Catalytic Membrane Reactor", *Chemical Engineering and Processing, Volume 44, Issue 11, 1 November 2005, Pages 1188-1196*.
3. Abashar, M.E.E.; Al-Rabiah, A.A. "Novel Multi-shell Membrane Reactors for Efficient Dehydrogenation of Ethylbenzene", *Engineering Sciences, Journal of KSU, Volume 18, No.1, 2005*.
4. Al-Rabiah, A. A., "Optimization of a Commercial Olefin Plant Using Pinch Analysis," CHISA 2004, Session H1, Paper 6, 22-26 August 2004, Prague - Czech Republic.
5. Al-Rabiah, A. A., "Membrane Technology for Hydrogen Separation in Ethylene Plants," 4th Ibero-American Congress on Membrane Science and Technology (*CITEM*), Brazil, July 16-18, 2003.
6. Al-Rabiah, A. A., "The Use of Hybrid Membrane/Distillation System for the Ethane/Ethylene Separation in Olefin Plants," 4<sup>th</sup> Ibero-American Congress on

Membrane Science and Technology (*CITEM*), Brazil, July 16-18, 2003.

7. Al-Rabiah, A. A., "Membrane Technology for Hydrogen Separation in Ethylene Plants," 4<sup>th</sup> European Congress of Chemical Engineering, Spain, September 21-24, 2003.
8. Al-Rabiah, A. A., "The Use of Hybrid Membrane/Distillation System for the Ethane/Ethylene Separation in Olefin Plants," 4<sup>th</sup> European Congress of Chemical Engineering, Spain, September 21-24, 2003.
9. Al-Rabiah, A. A., "Heat Integration of the Commercial Ethylene Process," 4<sup>th</sup> European Congress of Chemical Engineering, Spain, September 21-24, 2003.
10. Al-Rabiah, A. A., Timmerhaus, K. D., and Noble, R. D., "Design and Retrofit of the Refrigerated C<sub>2</sub> Splitter in an Ethylene Plant with a New Hybrid Separation System," 6<sup>th</sup> World Congress of Chemical Engineering, Melbourne, Australia, September 23-27, 2001.
11. Al-Rabiah, A. A., Timmerhaus, K. D., and Noble, R. D., "Membrane Technology for Hydrogen Separation in Ethylene Plants," 6<sup>th</sup> World Congress of Chemical Engineering, Melbourne, Australia, September 23-27, 2001.
12. Al-Rabiah, A. A., Timmerhaus, K. D., and Noble, R. D., "Retrofit Analysis of Replacing the C<sub>2</sub> Splitter in an Existing Ethylene Plant with a Hybrid Separation System," 76<sup>th</sup> Annual Meeting of American Association for Advancement of Science, Physical Sciences Session, Paper No.5, Las Cruces, New Mexico, April 9-12, 2000.
13. Al-Rabiah, A. A., Timmerhaus, K. D., and Noble, R. D., "Retrofit of the Refrigerated C<sub>2</sub> Splitter in an Ethylene Plant with a New Separation System," *AIChE 2000 Spring National Meeting*, Paper 55e, Atlanta, GA, March 5-9, 2000.
14. Al-Rabiah, A. A., Timmerhaus, K. D., and Noble, R. D., "Modeling and Simulation of Several Hybrid Distillation Systems for the Ethane/Ethylene Separation," *AIChE Annual Meeting*, Paper 221j, Dallas, Texas, November 1-5, 1999.
15. A. A. Al-Rabiah, K. D. Timmerhaus, and R. D. Noble, "Modeling and Simulation of Several Hybrid Distillation Systems for the Ethane/Ethylene Separation," *Proceedings of 20<sup>th</sup> International Congress of Refrigeration*, Session T1.5, Paper No. 070, Sydney, Australia, September 19-24, 1999.
16. A. A. Al-Rabiah, K. D. Timmerhaus, and R. D. Noble, "Investigation of Several Hybrid Distillation Systems for the Ethane/Ethylene Separation," *The International Congress on Membranes and Membrane Processes (Icom99)*, Session P5 (Hybrid Processes), Paper No. 2, Toronto, Canada, June 12-18, 1999.
17. A. A. Al-Rabiah, K. D. Timmerhaus, and R. D. Noble, "The Use of Hybrid Distillation for the Ethane/Ethylene Separation," 75<sup>th</sup> Annual Meeting of American

*Association for Advancement of Science*, Paper No. 128, Santa Fe, New Mexico, April 11-15, 1999.

18. Al-Rabiah, A. A., Timmerhaus, K. D., and Noble, R. D., "Investigation of Several Hybrid Distillation Systems for the Ethane/Ethylene Separation," *AIChE Spring National Meeting*, Paper 93b, Houston, Texas, March 14-18, 1999.
19. A. A. Al-Rabiah and K. D. Timmerhaus, "Development of a Hybrid Propane/Propylene Splitter in the Ethylene Process," *74<sup>th</sup> Annual Meeting of American Association for Advancement of Science*, Physical, Engineering and Information Sciences Session, Paper No. 2, Grand Junction, Colorado, May 17-21, 1998.
20. A. A. Al-Rabiah, K. D. Timmerhaus, and R. D. Noble, "Utilization of a Hybrid Membrane System in Ethylene Production," Presented at the *Tenth Annual Meeting of the North American Membrane Society (NAMS 98)*, Hybrid Processes Session, Paper No.3, Cleveland, May 16-20, 1998.
21. Al-Rabiah, A. A., Timmerhaus, K. D., and Noble, R. D., "Utilization of a Hybrid Membrane System in Olefin Production," *Proceedings of the 8<sup>th</sup> Ethylene Producers' Conference*, Vol. 5, 619-624, *AIChE*, New York, NY, 1996.
22. Al-Rabiah, A. A., Timmerhaus, K. D., and Noble, R. D., "Utilization of a Hybrid Membrane System in Olefin Production," *Proceedings of 5<sup>th</sup> World Congress of Chemical Engineering*, Vol. 4, 335-340, San Diego, CA, July 1996.
23. Al-Rabiah, A. A., Timmerhaus, K. D., and Noble, R. D., "Membrane/Distillation Hybrid Design for Propane/Propylene Separation," *AIChE Spring National Meeting*, Paper 63e, New Orleans, February 25-29, 1996.
24. Al-Rabiah A. A. and Soliman, M., "Heat Exchange Network Design for Ethylene Plants," *Proceedings of the third Engineering Conference*, College of Engineering, Vol. 1, 201-207, King Saud University, Riyadh, Saudi Arabia (1991).

## **Dr. Abdelhamid Ajbar**

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0506545654 (Mobile)  
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### **EDUCATION**

**Ph.D.** (Chem. Eng.), 1994, University of Notre Dame, USA

Dissertation: "*Robust Control and Monitoring of Discrete Time Feedback Control Systems*"

**MSc.** (Chem. Eng.), 1991, University of Notre Dame, USA

**Ingenieur D'Etat.** (Chem. Eng.), 1988, ENIM, RABAT, MOROCCO

### **EXPERIENCE**

**Professor**, 2003– Present

Dept. of Chemical Engineering, King Saud University, Riyadh, Saudi Arabia.

**Associate Professor**, 1998 – 2002

Dept. of Chemical Engineering, King Saud University, Riyadh, Saudi Arabia.

**Assistant Professor**, 1994-1998

Dept. of Chemical Engineering, King Saud University, Riyadh, Saudi Arabia.

**Graduate Teaching and Research Assistant**, 1989-1992

Dept. of Chemical Engineering, University of Notre Dame, USA

**Training at Shell Corporation Research Center, Houston, Texas, USA,  
May 1992-Sept-1992**

*Conducted research in Control and Fault Detection in Chemical Processes*

## **Current Interest:**

- Analysis, design and control of chemical and biochemical systems
- Applications of chaos theory to study hydrodynamics of multiphase reactors.

## **Sponsored Research Projects**

- Experimental investigation and modeling of chaotic behavior in gas-solid fluidized bed

Principal Investigators: Abdelhamid Ajbar, M. Asif, Khalid Al-Humaizi  
Sponsored by Research Center, College of Engineering, K.S.U.  
Status: Report Submitted

- Modeling, optimization and control of polyethylene reactors

Principal Investigators: K. Alhumaizi, A. Ajbar and E. Ali  
Sponsored by SABIC  
Status: Report Submitted

- Experimental investigation of chaotic behavior of hydrodynamics of gas-liquid bubble column reactors.

Principal Investigators: Abdelhamid Ajbar and M. Asif  
Sponsored by SABIC  
Status: Report Submitted

- Application of process synthesis techniques for design of waste water treatment plants

Principal Investigators: M. AlAhmad and A. Ajbar  
Research Center of College of Engineering, K.S.U.  
Status: Report Submitted

Sponsored by

- Advanced control and optimizations of MSF plants.

Principal Investigators: K. Alhumaizi, A. Ajbar and E. Ali  
Sponsored by KACST.  
Status: Report Submitted

- Experimental Investigation of reduction of particles agglomeration in Gas Solid Fluidized Beds

Principal Investigators: A. Ajbar and M. Asif  
Sponsored by SABIC..  
Status: Report Submitted

- Operational optimization of a lab Scale reverse osmosis desalination

Principal Investigators: K. Alhumaizi, A. Ajbar. E. Ali

Sponsored by Deanship of Scientific Research (National projects)  
Status:Ongoing

- Wastewater Management in the Petroleum Refineries in the Kingdom

Principal Investigators: A. Almutlaq, A. Ajbar and I. Almutaz  
Sponsored by KACST  
Status:Ongoing

- Experimental Investigation of Fluidization of nanoparticles

Principal Investigators: A. Ajbar and M. Asif  
Sponsored by Research Center, College of Engineering, K.S.U  
Status:Ongoing

## **Papers Published in International Research Periodicals**

1. Al-Rabiah and A. Ajbar , "Study of the Operability of a Continuous Bioreactor for the Pre-Fermentation of Cheese" *Engineering in Life Sciences* (in Press)
2. K. Alhumaizi, A. Alwan, and A. Ajbar., "Competition of plasmid-bearing and plasmid-free organisms in a chemostat: A study of bifurcation phenomena, Vol. 44, (2006), 342.
3. K. Alhumaizi and A. Ajbar, "Optimization of An Unstructured First-Order Kinetic Model of Cyclically Operated Bioreactors", *Journal of Environmental Engineering* Vol. 132,.( 2006), 453.
4. K. Alhumaizi E. Ali and A. Ajbar , "Study of Some Unique Features of Ratio-Dependent Models for Predator-Prey-Substrate Interactions In Continuous Cultures", *Chemical Engineering Communications* Vol. 193, (2006), 1164.
5. A. Ajbar, K. Alhumaizi and M. Asif, "Improvement of the Fluidizability of Cohesive Powders through Mixing with Small Proportions of Group A Particles", *Can. J. Chem. Engng. ,* Vol. 83, ( 2005), 930.
6. K. Alhumaizi and A. Ajbar, "Dynamics of Predator-Prey Interactions in Continuous Cultures", *Engineering in life Sciences*, Vol. 5, (2005), 139.
7. E. Ali, K. Alhumaizi and A. Ajbar, "Multivariable Control of A Simulated Industrial Gas Phase Polyethylene Reactor", *Ind. Eng. Chem. Res.*, Vol. 42, (2003), 2349.
8. A. Ajbar, "Classification of Static and Dynamic Behavior in Chemostat for Plasmid-Bearing, Plasmid Free Mixed Recombinant Cultures", *Chemical Engineering Communications*, Vol. 189, (2002), 1130

9. A.Ajbar, K. Alhumaizi, I Aidid and M. Asif, "Hydrodynamics of Gas Fluidized Beds with Mixture of Group D and B Particles", Canadian Journal of Chemical Engineering, Vol. 80, (2002), 281
10. A. Ajbar and A.H. Fakeeha, "Static and dynamic behavior of a class of unstructured models of continuous bioreactors with growth associated product". Bioprocess and biosystems engineering, Vol. 25, (2002), 21.
11. A. Ajbar, "Classification of stability behavior of bioreactors with wall attachment and substrate-inhibited kinetics. Biotechnology and bioengineering, Vol. 72, (2001),166.
12. A. Ajbar, "On the existence of oscillatory behavior in unstructured models of bioreactors" Chemical Engineering Science, Vol. 56, (2001) 1991.
13. A. Ajbar, K. Alhumaizi and S.S.E.H. Elnashaie, "Classification of Static and Dynamic Behavior in A Fluidized-Bed Catalytic Reactor", Chemical Engineering Journal, Vol. 84, (2001), 503.
14. A. Ajbar, "Classification of Static behavior of A Class of Unstructured Models of Continuous Bioprocesses", Biotechnology Progress, Vol. 17, (2001), 597
15. A. Ajbar and K. Alhumaizi, "Gas Phase Polyethylene Reactors: A Global Study of Stability Behaviour", IChEME, Vol. 79, (2001),195
16. A. Ajbar, "Stability Analysis of the Biodegradation of Mixed Wastes In A Continuous Bioreactor with Cell recycle" , Water Research, Vol. 35, (2001), 1201
17. A. Ajbar, "Stabilization of Chaotic Behavior in A two-Phase Autocatalytic reactor", Chaos, Solitons and Fractals, Vol. 12, (2001), 903.
18. A. Ajbar and K. Alhumaizi, "Microbial Competition: Study of Global branching Phenomena", AIChE J., Vol. 46, (2000), 322.
19. A. Ajbar and K. Alhumaizi, "Biodegradation of Substitutable Substrates in a Continuous Bioreactor with Cell Recycle: A Study of Static Bifurcation" , Mathematical and Computer Modelling, Vol. 31, (2000), 159.
20. A. Alhousseini, and A. Ajbar, Mass Transfer in Supported Liquid Membranes: A Rigorous Model ., Mathematical and Computer Modelling, Vol. 32, (2000), 465.
21. E. Ali, K. Alhumaizi and A. Ajbar, Model reduction and robust control of multi-stage flash (MSF) desalination plants., Desalination, Vol. 121, (1999), 65.
22. A. Ajbar, "Stability and Bifurcation of an Unstructured Model of a Bioreactor with Cell Recycle". Mathematical and Computer Modelling, Vol. 25, (1997), 31.

23. A.Ajbar and G. Ibrahim, "Periodic and Nonperiodic Oscillatory Behavior in a Model for Activated Sludge Reactors" *Mathematical and Computer Modelling*, Vol. 25, (1997), 9.
24. E. Ali, A. Ajbar, and K. Alhumaizi, "Robust control of industrial multi-stage flash desalination plants: ", *Desalination*, Vol. 114, (1997), 289.
25. Elnashaie, S.S.E.H. and Ajbar, " Period-adding and Chaos in Fluidized Bed Catalytic Reactors" *Chaos, Solitons & Fractals*, Vol.7, (1996), 1317.
26. Elnashaie, S.S.E.H. and Ajbar, A Chaotic, Non-chaotic Strange Attractors and Bistability in Non-isothermal Fluidized Bed Catalytic Reactors Under PI... , *Chaos, Solitons & Fractals*, Vol. 7, (1996), 1955.
27. A. Ajbar and S.S.E.H. , "Controlling Chaos by Periodic Perturbations in Nonisothermal Fluidized-bed Reactor", *AIChE Journal*, Vol. 42, (1996), 3008
28. Ajbar, H., M. R. Keenan and J. C. Kantor, "Optimal Linear Regulation with Hard Constraints", *AIChE Journal*, Vol. 41, (1995), 2439
29. A. Ajbar, and J. C. Kantor, "Time Domain Approach to the Design of Integrated Control and Diagnosis Systems," " Modeling of Uncertainty in Control Systems," Springer-Verlag, , (1994), 337.

## **KAMIL MUHAMMAD-ELHASSAN WAGIALLA**

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---

### **EDUCATION**

**PhD** 1973, Chemical Engineering, University of Manchester for Science and Technology (UMIST), England.

**MSc** 1970, Theory and Practice of Automatic Control, University of Manchester for Science and Technology (UMIST), England.

**BSc** 1969, Chemical Engineering, University of Manchester for Science and Technology (UMIST), England.

### **ACADEMIC EXPERIENCE**

1992 – Now: Professor, Department of Chemical Engineering, King Saud University.

1984 – 1992: Associate Professor, Department of Chemical Engineering, King Saud University.

1981 – 1984: Assistant Professor, Department of Chemical Engineering, King Saud University.

1979 – 1981: Senior Specialist, Gulf Organization for Industrial Consulting, Doha (Qatar).

1976 – 1979: Chemical Engineer, Saudi House for Industrial Consulting, Riyadh (Kingdom of Saudi Arabia).

1973 – 1976: Lecturer, Department of Chemical Engineering, Faculty of Engineering, University of Khartoum Sudan.

1970 – 1973: Demonstrator, Department of Chemical Engineering, UMIST (England).

### **SCHOLARSHIPS AND PRIZES**

1. President Aboud Prize for the top result in Sudan School Certificate (1963).
2. Shell Company Prize for best result in First year Examinations at the Faculty of Engineering, University of Khartoum(1966).
3. University of Khartoum Prize for best result in First year Examinations at the Faculty of Engineering, University of Khartoum(1966).

4. University of Khartoum Scholarship for undergraduate and post graduate studies at UNIST (England), 1966 – 1973.

## **SPONSORED RESEARCH PROJECTS**

- ***Production of ADA in Saudi Arabia Using C12 and C14-C18 Alpha Olefins. (Projects No. 153 and 154).***

Principal Investigators: Abdulrahman A. Al-Rabiah, Kamil Wagjallah  
Sponsored by ***SABIC through King Abdullah Institute for Research & Consulting***  
Status: ***Completed***

- ***Production of Plasticizer Alcohols in Saudi Arabia from Linear Alpha Olefins (LAO) Project No. 155***

Principal Investigators: Abdulrahman A. Al-Rabiah, Kamil Wagjallah  
Sponsored by ***SABIC through King Abdullah Institute for Research & Consulting***  
Status: ***Completed***

## ***Membership of Committees at Department of Chemical Engineering, King Saud University***

1. Demonstrators and Postgraduate Scholarship Students Committee.
2. Summer Training Committee.
3. Seminars and Social Activities Committee.
4. Laboratories and Experimental Equipment Committee.
5. Academic Plan Committee.
6. Member of College of Engineering Research Centre Administration Board.
7. Academic Committee of Department of Chemical Engineering.
8. Postgraduate Committee of Department of Chemical Engineering.
9. Deputy President of Examinations Committee for College of Engineering, King Saud University.
10. Membership of Consultative Editorial Board of Process Economics International Journal, England.

## ***Academic Courses Taught at King Saud University (Riyadh) and University of Khartoum (Sudan)***

1. Process Synthesis and Integration
2. Process Design and Economics
3. Process Control

4. Process Optimization
5. Computer-Aided Material and Energy Balances
6. Fluidization Engineering
7. Biochemical Engineering
8. Reactor Engineering
9. Chemical Engineering Principles
10. Chemical Industries
11. Chemical Engineering Applications in Waste Treatment
12. Chemistry of Engineering Materials

## ***Publications***

1. S.M.Al-Zahrani, A.M. Aljodai and K.M.Wagialla, 'Modelling and Simulation of 1,2-dichloroethane production by ethylene oxychlorination in fluidized-bed reactor', Chem Engng Sci, Vol 56, pp. 621-626, 2001.
2. Wagialla, K.M. and Elnashaie, S.S.E.H,' Bifurcation Behavior of Industrial Fixed Bed Catalytic Reactors for the Production of Phthalic Anhydride', Proceedings of the International CFIC 96 Conference, Fractals and Choas in Chemical Engineering, Editors, Giona, M. and Biardi, G., World Scientific, pp. 688-699, 1997.
3. A.H.Fakeeha, K.M.Wagialla and M.E.El-Dahshan,'Techno-Economic Assessment of Petroleum Coke Production for Carbon and Graphite Electrodes Manufacturing', Journal of King Abdulaziz University:Eng. Sci, vol 9, pp. 109-123 (1997).
4. Wagialla, K.M. and Elnashaie, S.S.E.H,' Bifurcation of Complex Dynamix in Fixed Bed Catalytic Reactors', Chem Engng Sci, Vol 50, no, 17, pp. 2813-2832, 1995.
5. Elnashaie, S.S.E.H., Wagialla K.M. and Helal A.,' Applicability of Fluifdized Bed Technology to Highly Exothermic Reactors', Presented at the 4<sup>th</sup> Canadian Chem Engng Conference, Halifax, Canada, Paper 1175, July 1990.
6. Wagialla, K.M. and Elnashaie, S.S.E.H. and Helal, 'Preliminary Investigation of Stability and Optimum Operation of Fluidized Bed Catalytic Reactors for the Production of Some Natural Gas Derivatives', Symposium on the Production and Processing of Natural Gas, Chem Engng Department, King Saud University, March 1992.
7. K.M.Wagialla, I.S. Al-Mutaz and M.E,Eldahshan, "The Manufacture of Soda Ash in th Arabian Gulf", Internation Journal of Production Econmics, England.

8. K.M.Wagialla and M.A. Soliman, 'Distillation Column Simulation by Orthogonal Collocation', Journal of King Saud University, Engineering Science.
9. K.M.Wagialla and S.S.E. Elnashaie, 'A Fluidized Bed Reactor for Methanol Synthesis. A Theoretical Investigation'. Industrial Engineering Chemistry Research, 30, 2298-2308 (1991).
10. S.S.E. Elnashaie, K.M.Wagialla and M.E.E.Abashar, 'The Use of Mathematical and Computer Models to Explore the Advantages of Fluidized Bed Technology for Catalytic Reactions with Equilibrium/Diffusional Limitations. Ammonia Synthesis', Mathematical and Computer Modelling Journal.
11. K.M. Wagialla, A.M.Helal and S.S.E.H Elnashaie, 'The Use of Mathematical and Computer Models to Explore the Applicability of Fluidized Bed Technology for Highly Exothermic Reactions. I.Oxidative Dehydrogenation of Butene', Mathematical and Computer Modelling Journal, 15, 1, 17-31 (1991).
12. S.S.E.H Elnashaie, K.M. Wagialla, and A.M.Helal, 'The Use of Mathematical and Computer Models to Explore the Applicability of Fluidized Bed Technology for Highly Exothermic Reactions. II. Oxidative Dehydrogenation of Ethyl Benzene to Styrene', Mathematical and Computer Modelling Journal, 15, 7, 43-54 (1991).
13. K.M. Wagialla, A.H.Fakeeha, S.S.E.H Elnashaie and A.Y.Almaktary, 'Modelling and Simulation of Energy Storage in Fluidized Beds using the Two Phase Model', Energy Sources, 13, 189-201 (1991).
14. S.S.E.H Elnashaie, K.M. Wagialla, 'Preliminary Investigation of the Fluidized Configurations of Ammonia Synthesis. A Mathematical Modelling Guided Approach', Chemical Industry (Journal of the Federation of Chemists and Technologists of Yugoslavia), 44,324-329 (1990).
15. I.S.Al-Mutaz and K.M.Wagialla, 'Production of Magnesium from Desalination Brines', Resources, Conservation and Recycling, 3, 231-239 (1990).
16. K.M.Wagialla, F.M.Ahabdan, S.S.E.Elnashanie and I.M.Mudalal, 'Evaluation of Alternative Unstructured Dynamics of Activated Sludge Process', Journal of King Saud University, Vol 1, Engineering Sciences (1,2), 1-25 (1989).
17. A.M.AL-Fadli, M.A. Soliman, K.M. Wagialla and I.S.Al-mutaz, 'A Network Model for the Optimal Planning of the Saudi Petrochemical Industry', Journal of Engineering Sciences, King Saud University, Vol. 14, Number 2, 295-309 (1988).
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## **Books**

1. K.M.Wagialla, I.M.Ahumaizy anf S.Alzahrani, 'Chemical Engineering Priniciples', Arab Home for Encyclopedia, Lebanon, 2003
2. K.M.Wagialla, 'Computer-Aided Material and Energy Balances for Chemical Engineering Students', Arab Scientific Publishers,Lebanon, 2005.
3. Jabir, O. Sabak and K.M.Wagialla, 'Applied Chemistry' ,,Ministry of Education Kingdom of Saudi Arabia, 1986

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## Education

Ph.D., University of California - Los Angeles, 1990

M.S., Cairo University, 1986

B.S., Cairo University, 1984

## Awards & Honors

AIChE CAST (Computing and Systems Technology) Directors Award, 2005

Best Speaker: PASI-CEPAC (PanAmerican Advanced Studies Institute, Chemical Engineering Pan American Collaboration) on Process Systems Engineering, 2005

Named Honorary Professor at Zagazig University, Egypt, 2003

The McFerrin Professorship, Chemical Engineering Department, Texas A&M University, 2002

The Walker Superior Teaching Award, School of Engineering, Auburn University, 2002

The Outstanding Faculty Member Award, School of Engineering, Auburn University, 2002, 1997, 1996, 1995, 1993, 1991

Auburn University Senior Faculty Research Award, 2001

Favorite Educator of the Year, The Mortar Board National Society, 2000

National Science Foundation, National Young Investigator Award, 1994

## Selected Publications

1. Kazantzi, V., X. Qin, M. El-Halwagi, F. Eljack, and M. Eden, "Simultaneous Process and Molecular Design through Property Clustering- A Visualization Tool", Ind. Eng. Chem. Res. (in press, 2007)
2. Eljack, F. T., M. R. Eden, V. Kazantzi, X. Qin, and M. M. El-Halwagi, Solving Process & Molecular Design Problems via Group Contribution and Property Clustering Techniques", AIChE J. (2007, in press)

3. Foo, D. C. Y., V. Kazantzi, ZM. M. El-Halwagi, Z. A. Manan, "Surplus Diagram and Cascade Analysis Techniques for Targeting Property-Based Material Reuse Network", *Chem. Eng. Sci.*, 61, 2626-2642 (2006)
4. Al-Otaibi, M. and M. El-Halwagi, "Targeting Techniques for Enhancing Process Yield", *Trans. IChemE, Part A: Chemical Engineering Research and Design*, 84(A10), 943-951 (2006)
5. Suardin, J., M. S. Mannan, and M. El-Halwagi, "The integration of Dow's fire and explosion index (F&EI) into process design and optimization to achieve inherently safer design," *Journal of Loss Prevention in the Process Industries* (2007, in press)
6. Qin, X., T. Mohan, M. M. El-Halwagi, F. Cornforth, and B. A. McCarl, "Switchgrass as an Alternate Feedstock for Power Generation: Integrated Environmental, Energy, and Economic Life Cycle Analysis", *J. Clean Techn. & Env. Polic.*, 8(4), 233-249, (2006)
7. Mohan, T., and M. M. El-Halwagi, "An Algebraic Targeting Approach for Effective Utilization of Biomass in Cogeneration Systems through Process Integration", *J. Clean Tech. & Env. Policy*, 8(3), 203-215 (2006)
8. Lovelady, E. M., G. Nworie, N. Shirlberg, M. M. El-Halwagi, J. Hill, H. Aglan, A. Bovell-Benjamin, and P. Gichuhi, "Development of a Computer-Aided Tool for System Description, Modeling, Analysis, and Integration for Screening Planetary Habitation Alternatives", *Proceedings of 36th International Conference on Environmental Systems*, Paper # 2006-01-2053, Pub. SAE International, Norfolk, Virginia (2006)
9. Brault, J. M., Milan, P. M., Nunez, M. C., El-Halwagi, M. M., Heitmann, J., Thibault, J., and Stuart, P., "Web-Based Teaching of Open-Ended Multi-disciplinary Engineering Design Problems," *Trans. IChemE, Part D Education for Chemical Engineers*, (2007, in press)
10. Foo, D. C. Y., Z. A. Manan, and M. M. El-Halwagi, "Correct Identification of Limiting Water Data for Water Network Systems", *J. Clean Tech. & Env. Policy* (2007, in press)
11. Bin Mahfouz, A. S., M. M. El-Halwagi, and A. Abdel-Wahab, "Process Integration Techniques for Optimizing Seawater Cooling Systems and Biocide Discharge", *J. Clean Tech. & Env. Policy*, 8: 203-215 (2006)
12. Almutlaq, A. and M. M. El-Halwagi, "An Algebraic Targeting Approach to Resource Conservation via Material Recycle/Reuse", *Int. J. of Environ. and Pollution (IJEP)*, (2007, in press)
13. Lovelady, E. M., M. M. El-Halwagi, and G. Krishnagopalan, "An Integrated Approach to the Optimization of Water Usage and Discharge in Pulp and Paper Plants", *Int. J. of Environ. and Pollution (IJEP)*, (2007, in press)
14. Grooms, D., V. Kazantzi, and M. M. El-Halwagi, "Scheduling and Operation of Property-Interception Networks for Resource Conservation," *Comp. Chem. Eng.*, 29, 2318-2325 (2005)
15. Eljack, F. T., A.F. Abdelhady, M. R. Eden, F. Gabriel, X. Qin, and M. M. El-Halwagi, "Targeting Optimum Resource Allocation Using Reverse Problem Formulations and Property Clustering Techniques," *Comp. Chem. Eng.*, 29, 2304-2317 (2005)
16. Kazantzi, V. and M. M. El-Halwagi, "Targeting Material Reuse via Property Integration", *Chem. Eng. Prog.*, 101(8) 28-37(2005)
17. Gabriel, F. and M. M. El-Halwagi, "Simultaneous Synthesis of Waste Interception and Material Reuse Networks: Problem Reformulation for Global Optimization," *Environ. Prog.* 24(2), 171-180, July 2005
18. Almutlaq, A., Kazantzi, V., and M. M. El-Halwagi, "An Algebraic Approach to Targeting Waste Discharge and Impure-Fresh Usage via Material Recycle/Reuse Networks, *J. Clean Technologies & Env. Policy*, 7(4), 294-305 (2005)

19. El-Baz, A. A., K. T. Ewida, M. A. Shouman, and M. M. El-Halwagi, "Material Flow Analysis and Integration of Watersheds and Drainage Systems: I. Simulation and application to ammonium management in Bahr El-Baqar drainage system", *Clean Techn. & Environ. Policy*, 7, 51-61 (2005)
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21. El-Halwagi, M. M., I. M. Glasgow, M. R. Eden, and X. Qin, "Property Integration: Componentless Design Techniques and Visualization Tools", *AIChE J.*, 50(8), 1854-1869 (2004)
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26. El-Halwagi, M. M., F. Gabriel, and D. Harell, "Rigorous Graphical Targeting for Resource Conservation via Material Recycle/Reuse Networks", *Ind. Eng. Chem. Res.*, 42, 4319-4328 (2003)
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29. El-Halwagi, M. M., 2003, "Industry and environmental biocomplexity: impact, challenges, and opportunities for multidisciplinary research" *J. Clean Technologies and Environmental Policy*, 4(3), 135
30. Dunn, R. F. and M. M. El-Halwagi, "Process Integration Technology Review: Background and Applications in the Chemical Process Industry", *J. Chem. Tech. And Biotech.*, 78(1011-1021), (2003)
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### **Education**

B.S. Chemical Engineering  
King Saud University, 1993

M.Sc. Chemical Engineering  
King Saud University, 1999

Ph.D. Chemical Engineering  
Texas A&M University, 2005

Ph. D. Resreach entitled " Productivity Enhancement Through Process Integration":

Ph. D. reseach was about developing hierarchical procedure to determine maximum overall yield of a process and optimize process changes to achieve such a yield. Targeting, path equations and interval analysis were among the tools used to identify overall yield ahead of detailed design. A mathematical program was developed for identification of cost-effective implementation of maximum attainable targets for yield. A trade-off procedure between the saving and expenses for yield maximization problem was presented. The proposed procedure is systematic, rigorous, and computationally efficient.

### **Professional Experience**

#### **1993 – Present**

- Researcher, SABIC R&T
  - Participated in many debottlenecking studies either performed internally in SABIC R&T or with external engineering contractors. Such studies covered Olefins, MTBE, Methanol, Ammonia and Urea plants.
  - Provided technical support for most of SABIC plants.

- Participated in several process tasks such as
  - Participated with a team from Shell Oil Company in assessing a SABIC/Shell joint venture company. The assessment includes location assurance review and compliance assessment review.
  - Worked as a facilitator for the quality advantage program where I conducted two sessions (two days each) for SABIC R&T professionals and one day session for operators/technicians. The program was prepared by organizational dynamics Inc. (ODI), USA.
- Developed simulation models for several plants/units including Ethylene, MTBE, methanol and Urea plant.
- Represent SABIC R&T in several committees within SABIC group such as utilities networking, ethylene technical exchange meeting, SABIC 2020 strategy development.
- Participated/conducted technical/economical evaluation for various technologies either commercial technologies or as proposals for development and commercialization.
- Provided technical support for the users of process simulation programs (Pro/II and Hextran) within SABIC R&T and SABIC affiliates.
- Conducted a survey for on-line leak sealing services in SABIC affiliates and led a team of SABIC R&T and affiliates to develop guidelines for handling the sealing services in SABIC.

### **Training (attended courses/seminars)**

- UOP engineering design seminar, UOP, Des Plaines, IL, ten weeks (3/9-10/11/1996) designated as UOP engineering fellow.
- Industrial liquid waste treatment, King Saud University, Saudi Arabia, 11-15 May 1994.
- Statistical and experimental design course, SABIC, 20-24 May 1995 (instructor: Dr. David Bacon).
- Practical distillation technology, IChemE, Manchester, UK, 21-23 November 1995 (instructors: Mr. Henry Z. Kister and Mr. John Brierley).
- Process heat exchanger course, Simsci, Houston, USA, 27 November- 1 December 1995.
- Reactor development and design course, IChemE & ChemEng, Dorset, UK, 6-9 October 1997 (instructor: Dr. L. M. Rose).
- Pyrolysis technology, AM Associates, Antwerp, Belgium, 5-9 September 1998.

- Pinch technology course, Linnhoff March, Manchester, UK, 5-9 October 1998.
- Advanced course on Distillation, absorption & extraction, Graduate school process engineering of the Netherlands, at University of Kaiserslautern, Germany, 18-22 October 1999.
- Industrial Membrane Separations, The Center for Professional Advancement, Amsterdam, The Netherlands, 19-22 June 2000, (instructors: Dr. Mark C. Porter and Dr. Thomas A. Davis).
- Several management and interpersonal skill development courses such as time management, presentation skills, technical report writing, project management, total quality management, Innovation and creative thinking, customer services quality advantage facilitator training.
- Leading High Performing Team, Oxford Management Centre, Dubai, UAE, 2-6 December 2006.
- Several simulation software training such as Pro/II, Hextran, Phenics (steam cracking simulator) and Icarus (cost estimation software).
- Basic GAMS training course, College Station, Texas, USA, 19-22 May 2003.
- Business planning and analysis for global chemicals, petrochemicals and plastics industries, Chemical Market Resources, Inc (CMR), Houston, Texas, USA, 16-17 December 2004.
- Fundamentals of selection, synthesis and design of thermal separation processes, Institute for pure and applied chemistry, University of Oldenburg, Riyadh, 4-8 November, 2006.
- As part of involvement in developing SABIC 2020 strategy, the following training programs were attended:
  - M1: Strategic planning tools, SABIC HQ, Riyadh, 28-29 August 2006.
  - M3: Financial modeling and analysis, SABIC HQ, Riyadh, 24-25 September 2006.
  - Part I: An introduction to organizational learning, SABIC HQ, Riyadh, 12-13 September 2006.
  - Part II: Building and sustaining organizational learning, SABIC HQ, Riyadh, 26-27 September 2006.
  - Part III: Building and sustaining organizational learning, SABIC HQ, Riyadh, 8 October 2006.

- Part IV: Building and sustaining organizational learning, SABIC HQ, Riyadh, 5 November 2006.
- Part VI: Building and sustaining organizational learning, SABIC HQ, Riyadh, 26 November 2006.
- Part VII: Building and sustaining organizational learning, SABIC HQ, Riyadh, 17 December 2006.

### **Symposium/Conferences (attended)**

- “2<sup>nd</sup> International conference on chemistry in industry”, Saudi Arabian chapter of ACS, at Bahrain, 24-26 October 1994.
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- “Chemputers Europe conference”, chemical engineering magazine, at Milan, Italy, 15-16 November 1994.
- “Distillation and absorption ‘97”, IChemE, at Maastricht, the Netherlands, 8-10 September 1997.
- “11<sup>th</sup> technical conference of Arab fertilizer association”, Arab fertilizer association, Doha, Qatar, 12-14 October 1998.
- “14<sup>th</sup> International Congress of Chemical and Process Engineering (CHISA 2000)”, Organized by Czech Society of Chemical Engineering, Praha, Czech Republic, 27-31 August 2000.
- The 2006 Annual Symposium of the Mary Kay O’Connor Process Safety, Texas A&M University, Texas, USA, October 28-29, 2003.
- AIChE 2004 Spring meeting, New Orleans, LA, USA, 25-29 April 2004.
- Symposium on Modeling of Complex Processes, Texas A&M University, Texas, USA, 1-3 March 2005.
- Mega Methanol Conference, Dubai, UAE, Centre for Management Technology (CMT), 6 - 7 March 2006
- Distillation and Absorption 2006, Organized by Institution of Chemical Engineers IChemE, Imperial College, London, UK, 4-6 September 2006.
- Several SABIC Technical Meetings (STMs), STM-1 in 1994, STM-2 in 1996, STM-3 in 1998, STM-4 in 2000 & STM-7 in 2006.

### **Publications**

- M. Al-Otaibi, M. Soliman, & A. Adirs, “Applying column targeting technique to the separation section of ethylene process” paper presented at CHISA 2000 (14<sup>th</sup>

International congress of chemical and process engineering), Prague, Czech Republic, 27-31 August 2000.

- M. Al-Otaibi, & M. El-Halwagi, "Inclusion Techniques for Integrated Yield Enhancement", AIChE 2004 Spring Meeting, 25-29 April 2004.
- M. Al-Otaibi, & M. El-Halwagi, "Targeting Techniques for Enhancing Process Yield", Trans. IChemE, Part A, Chemical Engg. Res. and Des., Oct., 2006, pp. 943-951.