Designing for Abnormal Situation Management®

Jamie Errington  
NOVA Chemicals Ltd.  
Joffre, Alberta, Canada

Peter T. Bullemer  
Honeywell Technology Center  
Minneapolis, MN, USA

Applying Abnormal Situation Management (ASM) Consortium’s Best Practices in the design of a new ethylene plant is changing the way NOVA Chemicals is approaching many design decisions. This new approach has been used to guide the design of the control center, training system and information management system. Anticipating abnormal situation management requirements in the initial development of the plant systems will enable improved operational effectiveness, and readiness to mitigate or avoid abnormal situations. An essential element in this approach is the understanding of the roles of various plant personnel in abnormal situation management and how plant system design impacts their ability to effectively perform their roles. Upcoming project activities will focus on alarm management, console design and graphical user interfaces as we continue to design for ASM.

The ASM Problem

NOVA Chemicals Ltd. is a member of the Abnormal Situation Management Joint Research and Development Consortium, a group formed in 1993 to understand and assess the problem of managing abnormal situations in the petrochemical and hydrocarbon industries. Having gained an understanding of the nature and scope of the problem, the ASM Consortium is now engaged in developing and testing approaches, which will prevent or mitigate the impacts of abnormal situations on our operating plants.

The ASM Consortium consists of 11 major petrochemical producers Amoco, BP, Celanese, Chevron, Exxon, Mobil, NOVA Chemicals, Texaco, Shell, Union Carbide, and; software developers Gensym and Applied Training Resources, university affiliates Purdue University, Ohio State University and the University of Toronto; and an industrial automation company Honeywell which is leading the program.

The ASM Consortium is the offspring of the Alarm Management Task Force, an independent Honeywell DCS (Distributed Control Systems) user group that had been formed to address the chronic problem of alarm management often identified by the situation of “alarm flood”. As this group explored the problems of alarm management, common to all similar computer-based control systems, the problem was seen to extend beyond alarm management practices. Moreover, the alarm management issues were

©User Centered Design Services, LLC 2002
found to be a manifestation of a larger problem that has become known as the ASM problem.®

**Understanding ASM Practices**

An abnormal situation probably occurs every day in each of our plants. Most are relatively small and are adeptly handled by the operating, maintenance and engineering staff in the plants with perhaps little impact on the unit. Examples of small events might be a controller pushed beyond its limits and placed in manual to stop cycling, or an operator entering the wrong setpoint value for a controller. “Some, though, result in poor quality product … A small percentage of abnormal situations mandate a process shutdown … And, a tiny fraction cause significant equipment damage, release of undesirable materials into the environment, and even human injury or death.”

“The broad description of an abnormal situation is that the process is disturbed and the automated control system can not cope. Consequently, the operations team must intervene to supplement the control system. The impacts to profitability may effect: product quality, equipment damage, injury or loss of life, job satisfaction, and/or product output.”

To gain an understanding of ASM, the ASM Consortium examined individual plant operations within member companies at many sites in North America and Europe. Some of the critical issues, which were identified, included:

- minimal understanding of the source of the problems and their impacts
- lack of human-system integration
- tendency to design for normal operation
- inadequate communication
- skeletal engineering / technical support
- inadequate training methods

The field studies confirmed published findings by the Chemical Manufacturers Association (CMA)™ that the initiating events were from three principle areas:

- equipment (40%)
- people (40%)
- process (20%)

“The vast majority (80-85%) of human errors primarily result from the design of the work situation (the tasks, the equipment, and the environment), which management directly control.” The ASM Consortium has found problems such as insufficient knowledge, procedure error, and operator error as being major factors contributing to the people component attributing to poor ASM.
Magnitude of the Problem

Often unreported, most abnormal situations are handled prior to their escalation to a major upset or catastrophe and without any identification of their impact. Only the major ones make the headlines. Over the past three years the ASM Consortium has been tracking the major newspapers which have reported many unfortunate situations including over 20 incidents each year, loss of lives, injuries, over 1 Billion $/year in direct losses and over 10 Billion $/year of indirect impacts to the North American economy.

The total impact of all of the abnormal situations, which are occurring in our plants, is far greater than that which is identified and reported. As an industry, we must get serious about eliminating these occurrences.

“Not by technology alone” must our industry address abnormal situations. The role of the operating, maintenance and engineering teams will play a pivotal part in reducing the occurrence and impact of abnormal situations. As the complexity and size of our new plants increase, and our demands on existing facilities grow, we need to:

- increase the skill of our staff
- ensure procedures are correct, that they deal with abnormal situations and are readily available to the operators
- create effective workspaces for the people in the plants so that they can perform their tasks
- design effective alarm management systems, knowledge of how to use alarms, filtering and suppression tools and provide alternate plant monitoring applications

Designing for Abnormal Situation Management

Thousands of decisions are made during the course of a project to design and build a world-scale ethylene plant. By utilizing the “ASM Best Practices” list compiled by the ASM Consortium from the site studies, NOVA Chemicals is attempting to “design for the abnormal” wherever possible as it builds a 2.8 Blb/year ethylene plant at the Joffre, Alberta site.

The project is a 50/50 joint venture project between NOVA Chemicals and Union Carbide Corporation (UCC) and is scheduled for startup in mid-2000. The plant is being built at the Joffre site where NOVA Chemicals currently owns and operates two ethylene and one polyethylene plant. The ethylene project is part of an overall expansion effort that is adding a second polyethylene and steam/electricity Cogeneration facilities to the site.

ASM Design Support Project Team

A small project team has been created with the goals of examining opportunities of applying the “ASM Best Practices” to the projects and to identify areas where early developments can be installed and tested in the existing Joffre facilities.

The team consists of individual project members from the detailed design teams, sponsorship and coordination from a central NOVA Chemicals group and key resources.
from leading Honeywell ASM experts, principally Mr. Ian Nimmo and Dr. Peter Bullemer who bring their extensive knowledge, skills and perspective to the project.

The deliverables from this team are a series of reports, which identify the opportunities, options, recommendations and an implementation plan for each of the study areas. The plans consider the individual project schedules, current infrastructures, testing/validation requirements, resources, technology and equipment requirements.

The ASM Design Support Project faces many challenges as it attempts to modify the traditional design methods, address the conflicting priorities and satisfy the many stakeholders. Large plant projects are usually driven by short term concerns in order to meet the startup dates and budget goals, and often do not consider the life-cycle implications of some of the ASM oriented decisions. This Ethylene project, by being a joint venture – has an additional set of management stakeholders to convince along with the huge task of designing one of the world’s largest ethylene plants.

**Control Center Design**

“Designing a control center effectively is an extremely complex task because of the multifunctional nature of the building:

- It’s a communication center
- It is the distribution, coordination and control center for plant work
- It’s a centralized local control focus for Ethylene Operation on the E3 plant
- It must be suitable for 24 hour operation in 12 hour shift system
- It’s the main training facility for operators
- It’s an emergency response center
- It’s a control application development center, used in the definition, design, testing and maintenance of software applications
- It’s a maintenance facility
- It’s an office facility for day-time operations, maintenance and technical support staff

Most importantly, the decisions made about the control center design significantly affect the nature of the operations tasks themselves as well as the effectiveness and efficiency in which the tasks are carried out.”

The design of the control center workspace was initiated with the development of a “participatory ergonomic system design approach”. The approach is intended to enhance the human performance in and around the control room and the complete manufacturing building. The enhancement derives from the consideration and integration of design factors that influence the comfort, health, safety, efficiency and effectiveness of people interacting with each other, process control equipment, information systems, communication systems, and other technologies and tools used within the control center environment. These participatory approach emphases the need to establish a multidisciplinary design team with strong participation from representative users of the environment.

The design process included six phases:
Control Center Role and Location

The initial activity surrounding the design of the Control Center was the determination of the control center role and location. The initial issue in establishing a shared vision was to decide on whether there should be a single central control building or multiple distributed control buildings. In addition, the team addressed the issue of whether to locate the building on or off site.

Though the trend in the industry is towards the use of a single, centralized building, our team concluded that multiple, on site buildings would be superior for these plants.

Large centralized control rooms serving several major units are often viewed as being more cost effective from both a construction and ongoing support basis than smaller centers serving specific plant operations. In our analysis, considerations such as environmental concerns around winter protection requirements for field operators, job rotation, training issues, intraplant communication and collaboration, and access to the process in an upset were all factors that supported a decision to move towards decentralized buildings.

Optimally operating major production facilities, solving problems and avoiding abnormal situations requires different skills and perspectives. Operating teams that can collaborate, communicate, share information and provide support to each other is well suited to meet that challenge. Separating the closely integrated roles of panel and field operators into physically different buildings and locations would drastically reduce the effectiveness of the operating teams at NOVA Chemicals. To encourage team collaboration means that we want to create an environment where field and panel operators are in direct contact with one another as frequently as possible. A single central location would demand that field operators work out of satellite rooms, where they would reside for the majority of their shift.

In the NOVA Chemicals environment, on-shift training is a very important aspect because operating technicians rotate their positions. To prepare for a new position, one-to-one on the job training is the principle mechanism to prepare for a new assignment. Field operators learn from watching and working alongside the panel operator to prepare for the change. If located in satellite rooms near their units, it is very difficult to prepare for the new assignment. In fact, it has been observed that with the distinct separation of panel and field operator work areas, two distinct cultures maybe created further widening the communication gap between the two groups and inhibiting the collaborative environment so needed to avoid abnormal situations.
Figure 1 – Joffre Site Plot
Control Center Workspace Design

The outcome of the first five design phases is six detailed design specifications for the following aspects of the control center:

- Manufacturing building arrangements – components include rooms for console operations, meeting, field operators, technical support, equipment, offices, maintenance, training, exercise, rest recovery, and personal hygiene
- Control room layout – definition of usable space, furniture and equipment, operational links, circulation requirements, maintenance access, workstations, backpanels, alarm annunciators, message boards, entrances and exits
- Workstation layout and dimensions – displays, controls, writing space, communication devices, seating
- Displays and controls design
- Environmental design – air quality and temperature, lighting, colours, noise, vibration, and static electricity
- Operational and managerial requirements – determination of compatibility with operational practices and organizational policies

The results of the first detailed design are illustrated in Figure 2 – E3 Manufacturing Building Layout and were the outcome of combined efforts of the ASM design support project team, the existing E1/E2 plant staff, the E3 project team and the design architectural design team of Brad Adams Walker Architecture.

The control center building is designed to provide a collaborative work environment that promotes the interaction of all groups effectively. The key adjacency requirements were identified and used to dictate the layout of the building. Many features are found in some control centers today, but few have attempted to address the workspace design in this complete manner and from the ASM collaborative work perspective.
Figure 2 – E3 Manufacturing Building Layout

The building is organized into four main areas, operations, maintenance, technical support (i.e., engineering) and common services. From the collaborative work perspective, the layout attempts to accommodate core team interactions with each other and the plant for each of the three main disciplines of operations, maintenance and technical support. In addition, the design addresses cross-functional team interactions in the adjacencies or interfaces between the main functional areas.

In the Northeast corner, nearest the plant is the Operations area. The main tasks performed in this area by operators are the monitoring and control of the plant, training, administration, meetings and the coordination of maintenance activities.

The monitoring and control is performed in the control room area with the large consoles arranged for the cracking and finishing areas of the plant. Adjacent support areas include training facilities for on and off shift, rest recovery, exercise, analyzers, meeting, technical support/applications, field operator area, kitchenette, and washroom. Team meetings can be accommodated behind the control consoles so those panel operators can participate without leaving their work areas. Support from technical staff is available from the applications area, where these people can monitor the process without creating
congestion at the operator console areas. The Field support area is arranged to provide workspaces for the Field operators when they are not required in the unit, and it is located beside the permit area. Maintenance staff coming through the building to go to the field, receive their permits to work at the permit desk from the Field Operators without having to go through the control console area.

The maintenance area is on the west and southwest sides of the building. Here facilities for shop space are provided as well as office areas. The maintenance planner, maintenance team leader, administration staff will use offices, while instrument and electrical staff will use a common large work area adjacent to the clean shop. A drop-in area is provided for additional shutdown planning staff in a central open work area.

The technical support staff is clustered into an area in the southeast, close to a central library area that will store the majority of the technical paper-based information.

The common services area include: a large common lunch area, library, file room, copy room, washrooms, locker room, meeting rooms and mechanical room. The use of the single lunch area is to encourage interactions between different team members to promote dialog and information sharing.

After completing the layout of the functional areas, we have begun the detailed design of the workstations in the control room and adjacent areas. This detailed design is driven by characterization of activity, information and communication requirements.

Overall this new process will demonstrate how we can design the workspace for ASM and achieve outstanding results.

Training Systems

The human performance demands in the petrochemical process control work environment challenge the traditional training strategies and methods. “Particularly, current training practices are observed to have a significant negative impact on ASM performance”\(^\text{viii}\). “Effective training for ASM requires the development of a training program that targets task-appropriate competencies and establishes a continuous learning environment”\(^\text{ix}\). A continuous learning environment is necessary because of the continuous dynamic nature of the plant environment.

A Broad Perspective

With the addition of any major new facility to a site, the need to provide a trained workforce for plant commissioning and startup is obvious. The practice of using the existing plants to provide the nucleus of skilled workers for the new plant places a tremendous burden on the overall level of competency remaining at those sites. Often this fact is overlooked, typically the major training program is created only for the new plant.

In 1984 when the second ethylene plant (E2) was added to the Joffre site, this problem was experienced first hand by NOVA Chemicals. An excellent, structured training
program was developed for the new plant startup which provided an outstanding foundation of skill for the startup and on into the plants operation. This program was used only for the startup.

The first ethylene plant (E1) was used as a resource pool to provide a strong nucleus of staff for the second plant (E2). Replacement workers were positioned in E1 without a formal training program to handle the large influx as existing programs were designed for individual additions. Plant performance and worker’s attitudes were affected and it took several years to reestablish the former level of competency and morale.

As the new facility is being built, the ASM Design Support group saw the requirement of developing a powerful and effective training program for the new facilities and their workforce. The group also saw an opportunity to prototype such a program in the E1 and E2 facilities which would not only provide key information to improve the program design, but would also avoid the experience of the earlier expansion in 1984. The goal would be to create a training program that would satisfy the demands of both startup and continuous plant operation.

Independent assessments of the E1 and E2 operations and maintenance staff had consistently identified that overall NOVA Chemicals has a very strong workforce. This workforce is well organized, has high ownership in the plant, good understanding of abnormal situation management, good use of procedures and an effective team system.

The effectiveness of the operating teams was based on a job rotation system whereby an operator progressed by moving through each and every position on the team. Everyone on the team is a trainer and is expected to train their replacement so that they can progress to their next position.

The weaknesses found by the assessments were:
- Inconsistent training
- Poor retrieval of information
- No scenario based training
- No formal testing of competencies
- Trainers were not “trained to train”
- No clear expectations of requirements to perform a role

Competency-Based Approach

We are establishing a competency-based approach to developing training systems that address the weaknesses of our previous practices. We are developing a prototype competency-based training program with the support of a training consultant, TTS Inc. Job competency models, which identify skills, knowledge, and attributes that individuals need to be successful in their jobs, are the foundation of the training program. The competency requirements are developed for each job, and these are communicated to individuals holding that position.

After completing the competency definition phase, we will develop the training curriculum based on job competencies and identified needs to certify operators and maintenance
technicians. The training curriculum will contain five levels of training implemented in the current team environment and culture at Joffre. The five levels are:

1. SHER (Safety, Health, Environment and Risk)
2. Plant Fundamentals
3. Process Overview
4. Process Specific
5. Job Specific

To support the job specific training (level 5) of the control panel operators, NOVA Chemicals is creating dynamic simulator of both the existing and new facilities. Development of a dynamic simulator is nearing completion for E1, and is underway for E3. E3’s model is being created currently to function as a design support tool in the examination of dynamic responses to upsets and changes, regulatory control design and other analysis. These models are being developed with ABB Simcon and will be used extensively later in the project in scenario based exercises as part of the Training Program.

Elements from the E1/E2 prototype program will be mapped across to provide the framework for the E3 program, as many of the roles and positions will be very similar. All staff hired for E3 will go through an introductory period in E1 or E2 including completion of the training program prior to assignment to E3.

**Information Management Systems**

Another key aspect of improving ASM practices is the timely capture and delivery of information to support job activities. Plant information management systems have the potential to become effective performance support systems. “A performance support system is one that can provide, on-demand, at the point of need, all of the information resources required to solve a problem or perform simple or complex tasks in support” of the operating unit. At NOVA Chemicals we are developing an on-line information management system that will improve ASM, training, and general plant performance. In addition, this system will lay the groundwork for adopting the next generation approach to collaborative decision support currently being developed by the ASM Consortium in the “NIST ASM/AEGIS program”. 

©User Centered Design Services, LLC 2002
Functional Components and Information Sources

The functional characteristics perceived to be important for an effective plant information management system are:

- Providing information (documentation, help, training, etc.) on-demand at the point of need
- Includes powerful and flexible search and navigation tools
- Incorporates multiple modes of presentation – text, video, audio, etc.
- Supports multiple deliver mechanisms – paper, on-line, CD-ROM, Internet/Intranet
- Provides customized views of the information to specific groups or individuals
- Provides a unified mechanism to access documentation, help, training and other learning and support products

The purpose of developing and storing all of the plant information is to help people gain the knowledge to operate the plant effectively. As the quantity of the information that is being managed in each of our facilities increases, we must apply some structure to it to make it useful. Without structure, the accessibility and availability of this information is drastically reduced. In a world where increasingly it is said that information and knowledge are power, a system that can organize, and deliver information on demand to each and every user, will redistribute power to all plant team members.

The information that is received and generated on a major project comes from many sources and will potentially be in many forms unless it is managed. Some of the sources include:

- Vendors
- Government agencies
- Consultants (EPC, design firms, general consultants, etc.)
- In-house (engineering, operations, maintenance, management, etc.)

The wide range of sources, if not controlled, will produce forms of wide diversity ranging from:

- Information delivered on paper from vendors
- Ad hoc memos, e-mails, reports generated electronically on a range of word processors types and versions
- Special application outputs from spreadsheets, presentation software, graphics tools, CADD programs, all of different types and versions
- Internet HTML formatted information

A Use-Based Strategy

Our information management strategy classifies the information based upon its intended use. Seldom used documents that are not critical to day to day operation, provided to the plant, may be left in their original paper format and classified as “paper based” information. The paper-based information will be catalogued and stored for possible future reference. Examples of this type of information might include some generic vendor information, proposal documents, etc.
More important information is classified as “electronic”, catalogued and stored in an Electronic Data Management system. It’s expected to receive infrequent use but is not required on-line to perform routine or nonroutine tasks. Electronic formats may include vendor specific types such as MS-Word or WordPerfect. Typical examples of this type of information are preliminary engineering calculations and corporate guidelines and information, Loss Prevention Standards, and Master Safety Data Sheets (MSDS).

The subset of information that is needed for specific tasks and is delivered on-line to directly support the plant operation is classified as “intelligent.” Examples of this key information category include Emergency Procedures, Standard Operating Procedures, training information, and process design manuals.

The “intelligent” component of this information is developed as it is authored into an XML (eXtensible Markup Language) format. This standardized (ISO) markup language allows the documents to be:

- Authored in a way that reduces the need for information maintenance
- Stored in a controlled database
- Independent of hardware and software platforms
- Storage form is ASCII
- Authoring and delivery applications are interchangeable
- Reuse of information
- Multiple applications can access documents
- Effective management of revisions
- Can be delivered to the user at the right time and place
- Content is captured using markups to identify context

NOVA Chemicals is examining the application of this technology through the development of a prototype application that is linked to the current Training Program development. The intent is that all major project documentation including key vendor information will be XML tagged and entered into the “intelligent” database.

**Conclusion**

We have described three areas where NOVA Chemicals is applying the knowledge gained by the ASM Consortium to the design of new ethylene plant. Specifically, this new approach has been applied to the design of the Control Center, training systems and information management systems. In future activities, the ASM Design Support Project Team will focus on:

- HazOp Analysis of the plant equipment and control system
- Alarm management and alarm objectives analysis
- Field communication systems
- Instrument and safety system design
- Incident reporting systems

The human-centered design focus coupled with an understanding of the abnormal situation management practice issues has produced a significant change to the project.
team’s deliverables. Based on our initial experiences in this project, NOVA Chemicals believes that this approach will improve human reliability and effectiveness and lower the probability of abnormal situations occurring in the new plant.

References: