CDR.12

Retrospective As-Built Schedule Development

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This paper presents the steps taken to develop an as-built schedule for a mechanical subcontractor on a refinery project in Venezuela two years after the project had been completed in support of an international arbitration. The mechanical subcontractor's contractual scope included structural steel fireproofing and erection, equipment installation, and piping prefabrication, painting and installation. A summary overview of the project's size, cost, schedule and delay issues is provided. The four steps required to perform the retrospective schedule development are documented. In addition, the average analyst-hours per activity required to perform these four steps are presented in order to provide owners, consultants, general contractors and subcontractors with a metric to estimate the effort required to develop a retrospective as-built schedule.

PROJECT SCOPE

The petrochemical plant is a $790 million Delayed Coker Complex, the purpose of which is to convert extra heavy crude oil to synthetic "sweet" oil at a rate of 108,000 barrels per day. The conversion process is accomplished by means of eliminating the coke and sulfur content of the crude oil, producing synthetic sweet oil. The plant consists of a storage area, a sweetening unit, a process unit, solid handling units and several buildings for control, maintenance and administrative processing.

PROJECT SCHEDULE

The start date of the project was July 19, 1999. The planned completion date was November 30, 2000 with a total planned duration of 501 calendar days. In actuality, the project did not finish until July 10, 2001 and took 723 calendar days to complete. Therefore, the project experienced a 7.4 month delay.

DELAY ISSUES

The mechanical subcontractor was faced with a host of problems. The variety of delay issues are listed as follows:

- Adverse weather in the form of unusually heavy rainfall.
- Inadequate coordination of the punch list process between the general contractor and owner.
- Interference of other subcontractors due to overcrowded conditions.
- Excessive welding requirements on the tower.
- The general contractor's poor project management performance.
- Late and poorly constructed foundations.
- Defective and late general contractor engineering.
- Late issuance of materials by the general contractor.
- Numerous owner-directed field changes.
- Labor strikes and slowdowns.

Due to these and other delay issues encountered on the project, the mechanical subcontractor was unable to complete its work scope in the contractually required time frame.

AS-BUILT SCHEDULE DEVELOPMENT PROCESS

Step One: Document Repository Development

Procedure—The first step involved the development of an internet-based document repository to store the images, optical character recognition (OCR) text, and auto-coded data fields for over 20,000 contemporaneous records comprising more than 175,000 pages. The mechanical subcontractor scanned the documents at 300 dpi and provided the TIFF scans to a data processing vendor. The images were further processed through an OCR program and auto-coded to capture objective data including the document date, author, recipient, subject and document type in searchable database fields. The OCR text, auto-coded data and scanned images were then uploaded to an internet-based repository with Boolean and advanced search capabilities.

Worker-hour Effort—The total man-hour effort is calculated on a per-activity basis for each step. The mechanical subcontractor's final schedule update contained 282 activities and was 82.5 percent complete as of January 19, 2001. However, the project did not finish until July 10, 2001. Furthermore, the mechanical sub-

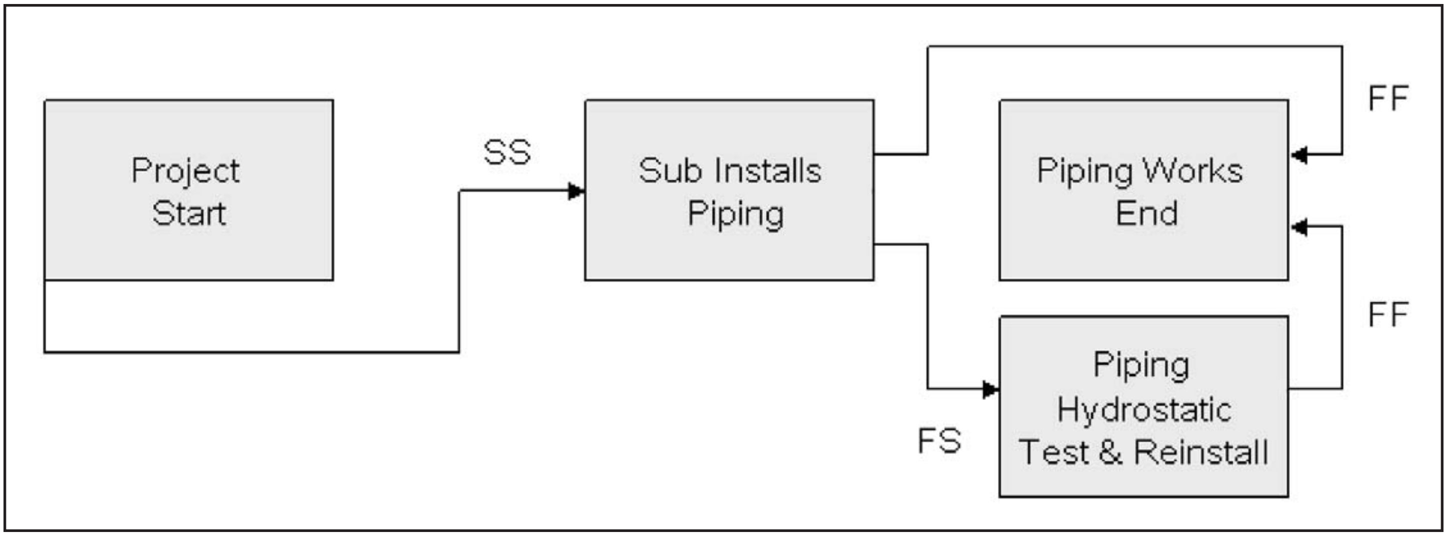

Figure 1—Piping Discipline Original Scope.

contractor's final schedule update lacked sufficient detail to properly perform the delay analysis. As a result, the as-built schedule was expanded to contain 1003 activities. The man-hour effort for developing the document repository, therefore, is based on the total man-hours spent on each step divided by 1003 activities to determine the man-hour effort for each activity.

The mechanical subcontractor scanned 175,000 pages over a period of three months using four scanners during both day and night shifts. The processing and uploading of the images took an average of seven days after receipt of each batch of files. The total man-hours expended on this step included approximately 4,200 scanning man-hours, 100 data processing man-hours and 25 management supervision hours. Therefore, the total effort equals 4.3 man-hours per activity. However, the document repository was also used to research claim issues and was not developed exclusively to validate as-built schedule dates.

Step Two: Reviewing the Existing As-Built Schedule for Scope and Logic Deficiencies

Procedure—The second step involved reviewing and correcting the existing as-built schedules for deficiencies. The schedule deficiencies included missing work scope, missing predecessor and successor logic, open ends and artificially imposed date constraints.

Worker-hour Effort—The elapsed time frame for this step was two weeks. The total man-hours expended completing this step equals 347 man-hours and 10 management supervision hours which translates to 0.4 hours per final schedule activity.

Step Three: Scope Additions and Logic Corrections

Procedure—The third step involved adding missing scope and correcting logic deficiencies in the existing as-built schedule for the piping, structural steel and equipment installation disciplines. Figures 1 and 2 show these schedule "fragnets" or sub-networks and can be used in the development of future schedules.

The scope and logic problems in the existing as-built schedule made it unsuitable for performing a schedule delay analysis. These issues had to be addressed before continuing with the analysis. The first problem was to add missing scope. There were no general contractor or owner activities represented in the schedule. This made it difficult to identify and allocate impacts. The schedule also contained numerous open-ends that needed to be tied to the start and finish of the project in order to calculate an accurate critical path. Figures 1 and 2 depict the respective before and after piping discipline fragnets. Figure 1 presents the original as-built schedule activities before scope was added to the piping discipline. Figure 2 presents the modified as-built schedule with the scope additions and logic corrections.

The material delivery process and the punch list process were not included in the original schedule. These missing activity chains were needed to depict the material delivery delays caused by the general contractor and inspection delays caused by two sets of unconsolidated punch lists issued separately by the general contractor and owner.

Increased detail was also added to the structural steel and equipment installation disciplines. This addition of scope in the three disciplines increased the activity count of the original as-built schedule from 282 activities to 1003 activities. The increase of 721 activities was necessary to account for the missing general contractor and owner work scope.

Worker-hour Effort—This phase spanned one month. A total of 182 man-hours was expended on the scope addition step. This translates to 0.2 man-hours per final schedule activity.

Step Four: Date Validation of the Enhanced As-Built Schedule

Procedure—The validation of the corrected as-built schedule dates was performed in the fourth and final step. Database source documents were used to validate the actual start and finish dates of each schedule activity. This step also required reviewing existing contemporaneous project documentation to identify reliable date validation source documents for the as-built schedule.

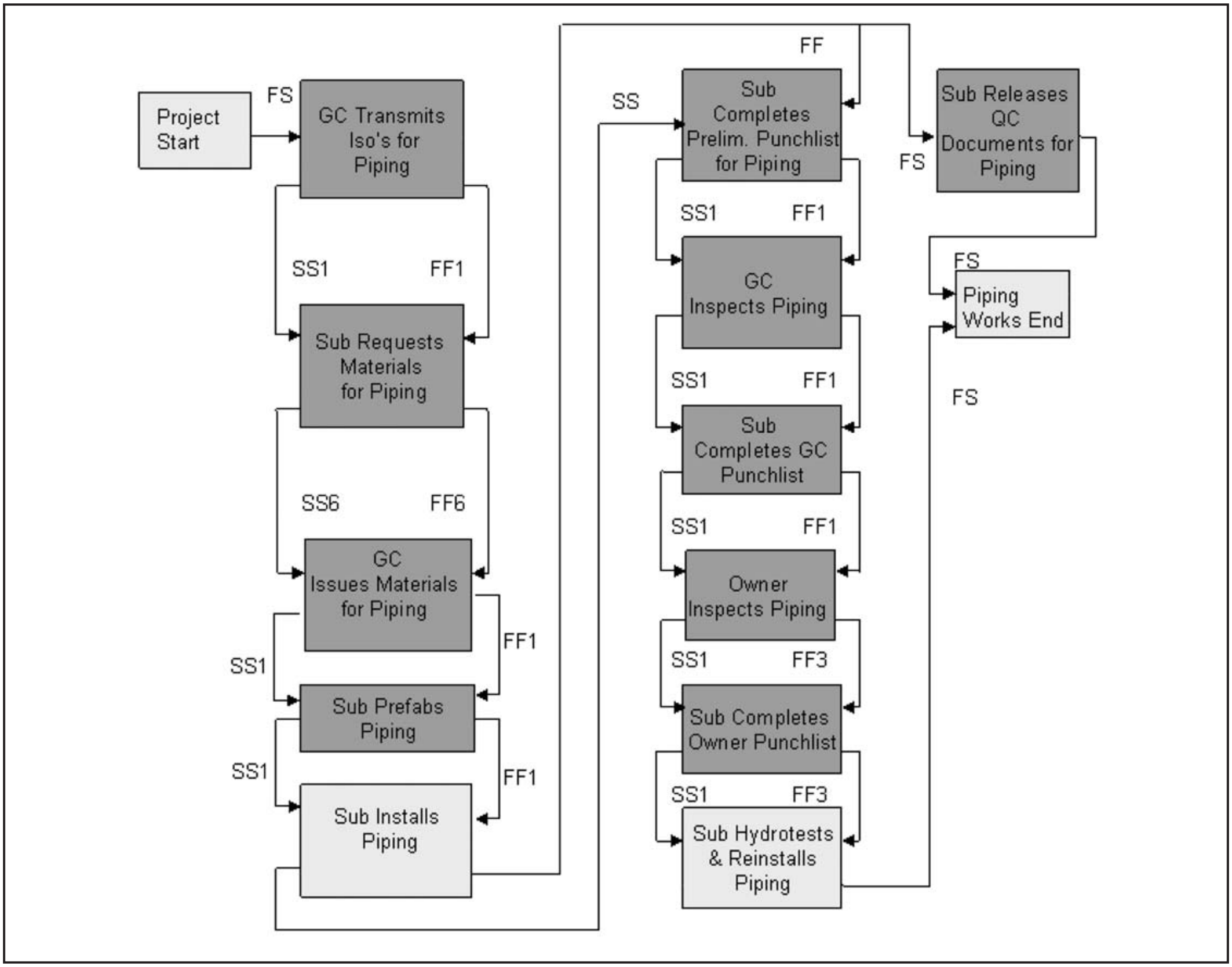

Figure 2—Piping Discipline Modified Scope.

Table 1—Reliability Code Definitions.

Reliability Codes	Description
1	Highly Reliable [primary source documents such as Acceptance Certificates or Material Receiving Reports]
2	Reliable [secondary source documents including tabular listings of schedule dates for system acceptances or walk downs]
3	Estimated by Long International based upon the actual dates of predecessor activities
4	Estimated by Long International based upon the actual dates of successor activities
5	Estimated by Long International based upon interpolations from meeting minutes, progress reports or other contemporaneous documents.
6	Mechanical subcontractor's schedule date [confirmed to be consistent with predecessor and successor dates]
7	Unconfirmed [Used mechanical subcontractor's unconfirmed schedule date as the default.]

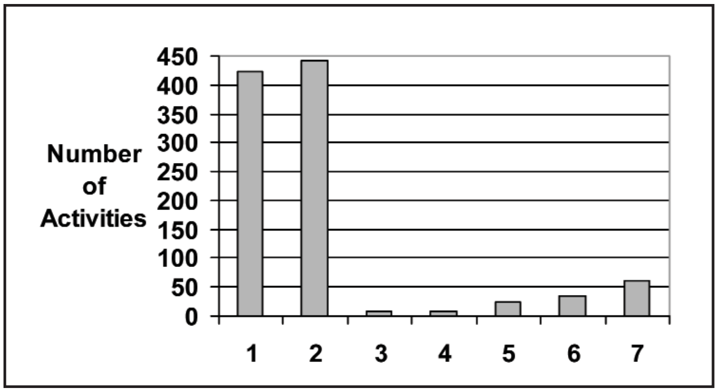

Figure 3—Reliability Code Distribution.

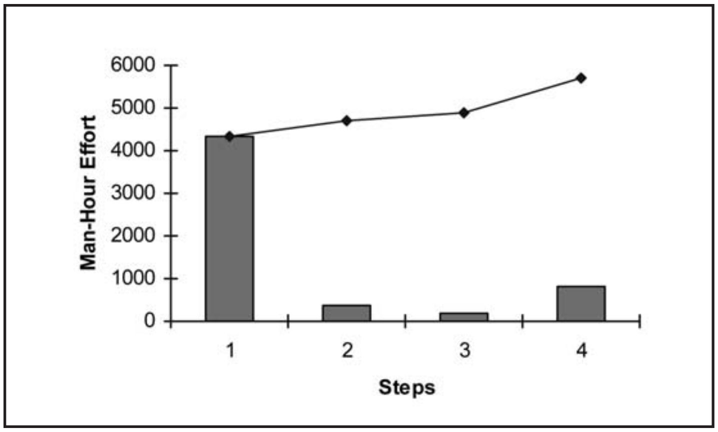

Figure 4—As-Built Schedule Total Man-Hour Effort.

The contemporaneous project documentation was contained in two sources: an internet-based document database discussed in Step 1 and a Microsoft Access database developed by the mechanical subcontractor. The problem with searching the internet database for contemporaneous project documentation was two-fold. First, not all the contemporaneous project records were scanned into the database, making the database incomplete. As a result, certain additional documents needed to be scanned to supplement the database. Secondly, the documents that did reside in the internet database were not coded consistently. For example, some documents were coded with a MM/DD/YY format while others were coded with a DD/MM/YY format. One document might have a US date format of 7/5/03 for July 5th, 2003 while another document might show July 5th 2003 using the South American date format of 5/7/03. In addition, hand-written document numbers were not coded into the database therefore many of the searches were very time consuming on a hit or miss basis.

The electronic Access database prepared by the mechanical subcontractor also was problematic. The main problem encountered was inconsistent data formatting between the database tables. There were over 100 database tables, each had thousands of records, where the same data was entered differently in each table. For example, the Isometric drawing numbers were sometimes entered with dashes, hyphens and other characters separating area and sheet numbers in certain tables. In other tables there were no characters separating the area and sheet numbers, or the area and sheet numbers were excluded from the Isometric drawing number altogether. Since the data formats were not identical in each table, there were many extra time consuming steps that had to be taken to correlate the information between the tables to the schedule activities to make them useful.

In addition, reliability codes and document bates numbers were assigned to the actual start and finish dates for each activity. The reliability codes identified the relative degree of accuracy of the actual dates. Table 1 describes the reliability codes from highly reliable, code 1, to unconfirmed, code 7, as-built dates. Each document used to validate a schedule activity start and finish date was given a reliability code.

The goal in the schedule validation step was to produce a final as-built schedule with the majority of the reliability codes being a one or two. Out of the 1003 activities in the as-built schedule, 865 activities (86 percent) were validated using a reliability code of a one or two. Figure 3 shows the distribution of activities for each reliability code.The result of this final step was the production of the enhanced as-built schedule.

This schedule was now acceptable to use for the schedule analysis.

Worker-hour Effort—This last step, the most time consuming step of all four steps, took a total of five months to complete. The total man-hour effort was 828 hours. This effort equals 0.8 man-hours per final schedule activity.

The development of the as-built schedule took a total of seven months to complete. Certain tasks were performed in parallel. For example, steps 1 and 4, involving the development of the internet database and the verification of as-built dates, overlapped by one month.

The total man-hour effort required to correct and validate the as-built schedule in the four-step retrospective approach is summarized in figure 4. The total man-hours expended on the entire process of developing the retrospective as-built schedule totaled 5692 man-hours. This effort correlates to 5.7 man-hours per final schedule activity.

However, the development of the internet database also supported numerous other claim research needs for the arbitration. If the man-hours associated with the internet database are excluded, the development of the as-built schedule took an average of 1.4 man-hours per final schedule activity.

The following guidelines are recommended to aid an owner or a contractor in the initial development of a schedule to minimize the need of a retrospective as-built schedule analysis:

- Ensure that the complete contractual scope is represented in the schedule. This includes scope requirements from both parties in the contract.
- Require that both parties sign off on each monthly update. This will ensure that the schedule is reviewed for accurate as-built and forecast dates.
- Discuss the schedule status during progress meetings. Accurate schedule status will be the result of such an implementation.
- Ensure there is accurate supporting documentation to back-up the monthly schedule updates. Progress meeting minutes,

daily logs, inspection certificates, etc. should be attached to each schedule update to support the actual dates.
- Continue statusing the schedule until the project is 100 percent complete.
- Use appropriate logic ties in the schedule. Make sure that each activity is tied to an appropriate predecessor and successor activity to ensure a realistic critical path. Do not have islands of isolated networks within the schedule.
- Avoid inconsistent data formatting in electronic databases. A user's manual should be developed and given to the data entry personnel to ensure consistency.

Proper implementation of these lessons learned may help to improve schedule management, avoid claims and minimize disputes.

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