POINT LEPREAU GENERATING STATION - 1995 SLAR PROGRAM

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The Pt. Lepreau SLAR Program began after the successful use of the SLAR MKIII Tool during the 1993 Pt. Lepreau G.S. Maintenance Outage. Preparations began immediately to assemble staff and equipment to complete a full core SLAR starting in April 1995. Installation and commissioning of the SLAR System at site began on March 29/95 and on reactor operations started on April 15/95. A total of 372 channels were visited with SLAR and all but 4 were dispositioned to the target life of 241, 500 Effective Full Power Hours. SLAR operations were completed on October 5/95 and within 7 days the Fuel Handling System was returned to pre-SLAR configuration and functionally tested. The SLAR Program was completed on schedule and within budget.

1.0 INTRODUCTION

The Point Lepreau Generating Station's Fuel Channel assemblies were installed with loose fitting garter springs (spacers). In some cases, the spacers had moved away from their design position resulting in contact developing between the pressure tubes and calandria tubes. Assessments had concluded that Zirconium Hydride Blisters could possibly form as early as 1995 at some of these contact locations.

Initially, to address blister concerns, NB Power's fuel channel strategy was to perform a Large Scale Fuel Channel Replacement at Pt. Lepreau scheduled to begin in April 1998. It was planned to use the SLAR technology to target the high risk channels which could have a potential to form Zirconium hydride blisters prior to the retube date.

The performance of the SLAR MKIII Tool during the 1993 outage met all expectations with respect to finding and moving spacers and resulted in a reassessment of the pressure tube strategy. It was determined that a full core SLAR program was cost effective and could be completed within a 6 month window. A full core SLAR program would address the problem of pressure tube and calandria tube contact and would allow the existing pressure tubes to operate for their design life (210,000 EFPH).

The SLAR Project Group was formed and was given the mandate of conducting a full core SLAR Program to start in April 1995. This would allow the pressure tube to be Slarred at approximately 100,000 EFPH, which was the maximum used in the design of the SLAR Tool.

2.0 PREPARATION

The SLAR Project Organization was staffed mainly from within NB Power with contracts awarded to the Ontario Hydro SLAR Group and AECL to provide assistance during the preparation phase. The SLAR equipment had last been used at Hydro Quebec - Gentilly 2 in 1991 so it was immediately assessed to determine its condition then shipped to the Pt. Lepreau site for rework. The equipment was disassembled and decontaminated at site and then was sent to AECL, Sheridan Park Engineering Laboratory (SPEL). The front cradle was reassembled and paired with a spare rear cradle. Once the Delivery System was completely reassembled, it was calibrated and commissioned by AECL and NB Power personnel. This activity was used as a training exercise for site staff. Ontario Hydro SLAR staff commissioned the inspection system and when complete, the full SLAR System went through an Integration Test. Once the system was ready for service, it was disassembled and shipped to site ready for installation.

AECL was awarded a contract to supply 9 MKIII SLAR Tools for use during the outage. The first tool was required in June 94 so it could be installed in the newly assembled Delivery Machine to support commissioning and training activities.

In order to operate and maintain the SLAR System on a 24 hour basis for a 6 month outage, a large number of personnel had to be trained. Using the existing Fuel Handling Unit as the core group, the SLAR Project seconded staff for operation and technical activities. This resulted in the Fuel Handling Organization increasing by more than 3 times its normal size.

A key element of the SLAR Project was the training of personnel to operate and maintain the SLAR equipment as well as provide the supervision and technical support to the project. A large number of courses were developed by NB Power SLAR staff, AECL and Ontario Hydro and given during the period from Jan/94 to April/95. A total of 3255 person days of SLAR training were completed in 1994 and 278 person days in 1995. This resulted in having staff that were familiar with the systems prior to commissioning at site.

In addition to personnel to operate and maintain the SLAR System, personnel were seconded to provide technical support. A total of 23 Work Plans, 10 Operating Manuals or Instructions and 7 Maintenance Procedures were prepared. Site wiring had to be modified to interface the SLAR System with the existing system. As well, technical support was required on the Delivery System rebuild and testing ongoing at AECL.

2.1 Software

In order to interface the SLAR System with Digital Control Computer Y (DCCY), it was necessary to modify DCCY hardware and software. The hardware modifications were completed in the fall of 1994 during a scheduled DCCY outage. The incorporation of the SLAR Software resulted in 135 new programs being installed and 90 Computer Software patches being implemented.

All SLAR software was fully tested at AECL then tested on DCCZ at site prior to installation in DCCY. The software was installed in DCCY's Bulk Memory Unit and then invoked when required for use. The procedure of invoking software, when it is necessary, was developed for Grappling and Defuelling software and allowed computer personnel to test SLAR software on Fuel Handling Maintenance days, prior to the outage. This enabled the SLAR System to be completely commissioned prior to the reactor shutdown.

3.0 IMPLEMENTATION

The SLAR Project Implementation Organization (Figure 1) was established in mid March 1995, approximately 1 month prior to the outage start. The objective was to begin Slarring channels within 24 hours after the shutdown started. In order to achieve this, the reactor had to be prefuelled enough to allow the fuelling system to be removed from service approximately 2 weeks prior to the start of the outage. Commissioning activities were performed on a 24 hour basis once the reactor prefuelling was completed.

The fuelling machines were removed form service on March 29/95. Removal of the West Fuelling Machine, installation and commissioning of the SLAR System and modification of the East Fuelling Machine began on a 24 hour basis. Once the system was fully installed, commissioned, and functionally tested on the Rehearsal Facility, the tool that had been used at SPEL and for commissioning was removed and replaced with a new tool. On reactor operations began on April 15/96 on channel W14. The procedures used to install and commission the SLAR system ensured no critical path time was lost on these activities.

3.1 Mechanical Failures

During the planning stages for the SLAR campaign, it was postulated that one SLAR Delivery Machine Rear Cradle replacement would be required along with one Mechanical Ram change. Both of these replacements would be required to replace components that were at the end of their service life. In fact, the rear cradle had to be replaced three times and the mechanical ram three times.

The SLAR Rear Cradle had to be replaced 32 channels into the outage due to an eccentric tube failure. The eccentric tube bridges the gap through the turret for the Hydraulic and Mechanical Rams. The eccentric tube mechanism failed resulting in it not rotating to its proper position preventing the proper extension of the Hydraulic

Ram. The rear cradle replacement took approximately 5.5 days to complete, including the tool change. Late in the outage, the eccentric tube failed again resulting in a rear cradle replacement. A planned removal of the rear cradle was completed after it had completed approximately 250 channels and this was required due to component wear.

The Mechanical Ram had to be replaced three times due to Latch and B Ram drive failures. The design of these rams is from Gentilly-1 and will require additional testing prior to being used again.

The East Fuel Receiving Machine failed in early August resulting in two days downtime. The guide sleeve could not be removed from the snout due to a latch tang failure. The channel was frozen off and drained with fuel still in the channel and the East FR/M was removed. The fuel in the channel was uncovered for approximately 35 minutes. This procedure was possible only because the reactor had been shutdown for approximately 15 weeks.

In total, these major mechanical problems cost the project approximately 35 days down time.

3.2 SLAR Tool Performance

A total of nine SLAR MKIII tools were purchased for the SLAR Project. Eight tools were used to complete the 372 channels. Table 1 provides details on when the tools were installed, removed, channels completed and the reason for removal.

SLAR Tool SLNB#2 was used for commissioning activities at SPEL and at site. This tool was removed prior to starting on reactor operation and testing showed it to have deteriorated in its meggar readings. Subsequent investigation by Ontario Hydro indicated that water ingress into the LIM was the cause of the problem. The tool was reworked at AECL and was assigned number SLNB#10.

Prior to the Pt. Lepreau SLAR Program, SLAR Tools were removed from service due to a window being complete. The tools were not normally spent but were replaced to prepare for the next window. It was necessary at Pt. Lepreau to operate the tools for as long as possible to try and minimize tool usage. The original design cycle limits [1] are as follows:

2000 cycles less than 73% of full bending pressure
and
2000 cycles less than 57% of full bending pressure

Due to the number of cycles required to complete a channel, these cycle limits were not adequate. On average, Pt. Lepreau would have had to replace the tool every 26 channels using these limits rather than every 50 channels that was planned.

A reassessment of cycle limits was undertaken and based on bending pressure, fatigue failure theory and safety factors for design, the following limits were arrived at:

- less than 5000 cycles between 41-73% full bending pressure, or
- less than 6000 cycles between 21-73% full bending pressure, or
- unlimited cycles less than 21% full bending pressure.

The new limits permitted tools to complete approximately 60 channels without being replaced due to bending cycles. Table 2 provides information on cycles used for each tool and total number of channels completed.

The SLAR Tool replacement procedure took approximately 24 hours to complete with an additional 20-24 hours required for calibration. The SLAR Tool Linear Induction Motors (LIM) functioned without problems for the outage and there were no controller trips due to leakage current from the LIM's. All tools removed were inspected for abnormalities prior to being put into storage and none were noted.

3.3 Channel Processing Procedures

The SLAR process was required on 372 of the 380 reactor channels. Of the eight channels not requiring SLAR, channel K05 was replaced in 1989 and tight fitting spacers were installed at that time. The remaining seven had been dispositioned to the target life without contact using Slarette.

Fuel Cooling during the channel defuelling process was a concern because the SLAR tool could block shutdown cooling flow down the channel while the fuel was being pushed into the Fuel Receiving Machine. A detailed analysis was completed by the Nuclear Safety Group [2] and it resulted in some constraints on the channels that could be Slarred. For the first two weeks of the outage, channels were selected on the basis of the channel power at shutdown. This ensured that if the SLAR Tool became stuck in a channel during defuelling, the fuel would still be adequately cooled.

3.4 Channel Processing Data

The SLAR outage duration was 24.6 weeks. The average time to process a channel from Delivery Machine clamp to unclamp was 7.4 hours. The average time just Slarring a channel was 5.87 hours with the remaining time being spent on defuelling, refuelling and moving between channels. Figure 2 shows the average time spent on a channel and the average channel spacer movement required plotted against the reactor rows.

Figure 3 provides a representation of what percentage of time on channel was used to completed the different tasks such as Bump & Scan, Final Pass, etc. Access Control was in effect for the East side of the Reactor Building during SLAR and entries to this area were minimized so SLAR processing would not be affected.

3.5 SLAR Channel Results

The target life used at Pt. Lepreau was 241,500 Effective Full Power Hours (EFPH). This target was arrived at by taking the pressure tube design life of 210,000 (EFPH) and incrementing it by 15% to account for nominal pressure tube dimensional parameters being used, along with accounting for model inaccuracies. As left spacer loading was targeted to be greater than or equal to 67 Newtons, where possible. Channel target life took priority over spacer loading. In some cases the spacer loading target was not considered in order to get a better channel gap profile.

Four channels of the 372 completed do not meet the target life. Three of these channels (F09, O09, P14) meet the design life target but do not have the 15% margin.

Channel D04 is presently in contact but not on the outlet end. Channel D04 spacers were all found in the inlet end bell. Four attempts were made to move the spacers, but only one spacer was successfully moved into the channel. The remainder will not move beyond the 520 mm position. The spacer that was moved into the channel was moved to the outlet end and its position was optimized to prevent contact on the outlet end of the channel. The Blister Assessment Study done for Pt. Lepreau predicts this channel should not be at risk to blister formation until approximately the year 2009. This channel will be added to the In Service Inspection Program.

The objective of the SLAR Program was to locate all spacers in a channel. In 93% of the channels completed, four spacers were identified even though in some cases three were only required to obtain a solution. Extra time was not spent trying to locate a fourth spacer once SLAR personnel were convinced the fourth spacer was not in the channel but in one of the end bells.

Spacers having a calculated load of less than 67 Newtons were considered to be unloaded. When a spacer was left unloaded in a channel, additional analysis was performed using the following spacer configuration cases:

Case 1 - The unloaded spacer in it's actual as left location,

Case 2 - The unloaded spacer not considered in the analysis, Case 3 - The unloaded spacer is placed at the location of minimum gap in the target life prediction of Case 2.

In each of the cases, a prediction of no contact prior to target life was required. Seven channels met the target life criteria but have spacer loading that falls below the 67 Newton target and do not meet all the cases indicated.

3.6 Spacer Movement Data

Table 3 summarizes the spacer movement data for all the channels completed. In all, spacers had to be moved slightly less than a kilometer (941,800 mm) so target life could be met. The average total spacer displacement from design for a channel was 3107 mm while on average, the channel spacers had to be moved a total of 2531 mm to meet the target life. Each time the Linear Indication Motors were fired, the spacer moved 33.6 mm on average.

All SLAR activities were carried out from the west side of the reactor. The spacers were numbered 1-4 starting on the west side, closest to the Delivery Machine. It appears from reviewing the data that on average spacer four moved the furthest from its design position while spacer one moved the least. The spacers on average moved more to the west end of the reactor than the east end and channel flow direction does not influence the direction of spacer movement. These results are included in Table 4.

3.7 Cracked Blister System Usage

Cracked Blister System (CBS) scanning was performed on channels predicted to reach the blister formation threshold [3] on or before 11.9 years of hot operation with less than a three year margin of safety ($\leq$ 14.9 hot years). The upper bound numbers were used to determine the time to blister formation. A total of 68 channels fell into this category.

In addition, ten channels predicted to reach blister formation after 14.9 hot years but with an initial hydrogen concentration of $\geq$ 10 ppm were included. This resulted in 78 channels being scanned with the Cracked Blister System. A scan was performed prior to jacking in the channel and if there was contact predicted prior to 116,500 EFPH then a scan was performed once Slarring was completed.

There was no evidence of cracked blisters in any of the channels completed. Two channels did exhibit indications within the contact region that were greater than 100% Full Scale Height. These indications were not changed by the SLAR process and are believed to be due to outside surface anomalies on the pressure tubes. No further inspection as a result of Cracked Blister System scanning was necessary.

4.0 QUALITY VERIFICATION

In order to ensure the SLAR objectives were achieved, a verification process was set up to review data after the channels were completed. This process provided an independent review of the following:

Spacer Verification:

> The Eddy Current Spacer Detection Data was reviewed for each channel to confirm "as found" and "as left" locations were correct. The SLARON runs were then verified or repeated, if necessary, to confirm target life was achieved.

Ultrasonic Fast Scan Cracked Blister Verification:

> The data from the Cracked Blister System Scanning was independently verified. This included calibration and evaluation of all repeatable indications.

Data Base Verification:

Entries to the SLAR Data Base were verified to be correct and when all aspects of the verification process were complete, the channel was flagged as being complete in the data base.

The verification process proved to be a valuable asset in confirming that channel status was well documented.

5.0 WORK ORDERS / MANHOURS / FINANCIAL

Field work done at Pt. Lepreau is done using a WORD (Work Order Report of Deficiency). A total of 1088 WORDs were completed in support of the SLAR Project, with a total manhours of 19,628.

In the early stages of the SLAR Project, a budget was prepared along with projections on the total man-hours required. Figure 4 indicates the planned and actual cumulative man-hours for the project. Monthly executive reports were prepared detailing actual project costs as compared to the budget. Figure 5 provides the final cost breakdown for the SLAR Project.

6.0 CONCLUSIONS

1.0 The 1995 SLAR Program at the Point Lepreau Generating Station was very successful and resulted in all but one channel being depositioned to pressure tube design life without contact.

2.0 The SLAR Program was completed on time and within budget.

REFERENCES

[1] J. ERVEN, " Mark III SLAR Tool Design Requirements", Technical Document TD-SLAR-30110-T6, June 1, 1992

[2] D. EDGAR/R.A. RICHARD, "Technical Basis for Fuel Cooling and Heat Sinks Under Shutdown Cooling Conditions", PLGS-IR-03556-XX

[3] M. JORGENSEN, D. MOONEY, "Point Lepreau Preliminary Pressure Tube Blister Susceptibility Assessment", AECL 87-31100-220-034, June 1994

Table 1
Tool History

Tool Number	Date Installed	Date Removed	Number of Channels Visited	Number of Channels Completed	Comments
SLNB-7	95/04/15	95/04/30	32	32	Tool 7 was replaced because the Delivery Machine's rear cradle was replaced.
SLNB-3	95/05/05	95/05/29	61	60	During tool calibration, it was found that blister probe #2 was defective. Tool 3 was replaced during repairs to the magazine rotor. The number of bending cycles was just slightly less than the upper limit. When the tool was removed, it was found that the horizontal joint pins had failed.
SLNB-9	95/06/02	95/06/22	57	57	Tool 9 was replaced because the number of bending cycles was very close to the upper limit.
SLNB-8	95/06/24	95/07/19	65	65	Tool 8 was replaced because the number of bending cycles was very close to the upper limit.
SLNB-6	95/07/23	95/08/09	48	47	Tool 6 was replaced because of a rear cradle change.
SLNB-5	95/08/14	95/09/11	65	62	Tool 5 was replaced because the number of bending cycles was very close to the upper limit.
SLNB-4	95/09/12	95/09/25	26	26	Tool 4 was replaced because a rear cradle change was required.
SLNB-10	95/09/28	95/10/05	23	23	SLAR complete.

SLAR Tool Performance Summary
Table 2

Tool Number	Tool 7	Tool 3	Tool 9	Tool 8	Tool 6	Tool 5	Tool 4	Tool 10
Number of Channels SLARed	32	61	57	65	48	65	26	23
Total Number Of Cycles Used	3991	7108	6420	6106	5772	6512	3269	2194
Number of Cycles Used Between 21-41% Of Full Bending Pressure	632	1582	1365	1128	709	1447	616	424
Number of Cycles Used Between 21-73% Of Full Bending Pressure	3590	6258	5682	5332	5173	5563	2663	1949
Number of Cycles Used Between 41-73% Of Full Bending Pressure	2958	4676	4317	4204	4464	4116	2047	1525
Number of Hours 'In Channel'	247	458	375	407	282	431	185	109
Time in Use (Days:Hours:Min) {Excluding Breakdown Time}	13:12:50	21:19:50	19:05:30	19:15:07	14:08:17	20:12:09	8:20:41	5:09:12
Average Number of Cycles (Total)/Channel	124.72	116.52	112.63	93.94	120.25	100.18	125.73	95.39
Average Number of Cycles (21-73% Full Bending Pressure)/Channel	112.19	102.59	99.68	82.03	107.77	85.58	102.42	84.74
Average Number of Cycles (41-73% Full Bending Pressure)/Channel	92.44	76.66	75.74	64.68	93.00	63.32	78.73	66.30
Average Time/Channel (Hours:Mins)	10:09	8:35	8:06	7:15	7:10	7:34	8:04	5:15

TABLE 3

SPACER MOVEMENT PARAMETERS

REACTOR TOTALS	
TOTAL SPACER MOVEMENT	941,800 MM
TOTAL LIM FIRES	28,059
TOTAL RAM END LIM FIRES	25,392
TOTAL JACKING CYCLES	47,671
AVERAGES	
AVERAGE CHANNEL DISPLACMENT FROM DESIGN	3,107 mm
AVERAGE SPACER MOVEMENT TO MEET TARGET LIFE	2,531 mm
AVERAGE MOVEMENT PER LIM FIRE	33.6 mm

TABLE 4

SPACER DESIGN DISPLACEMENT

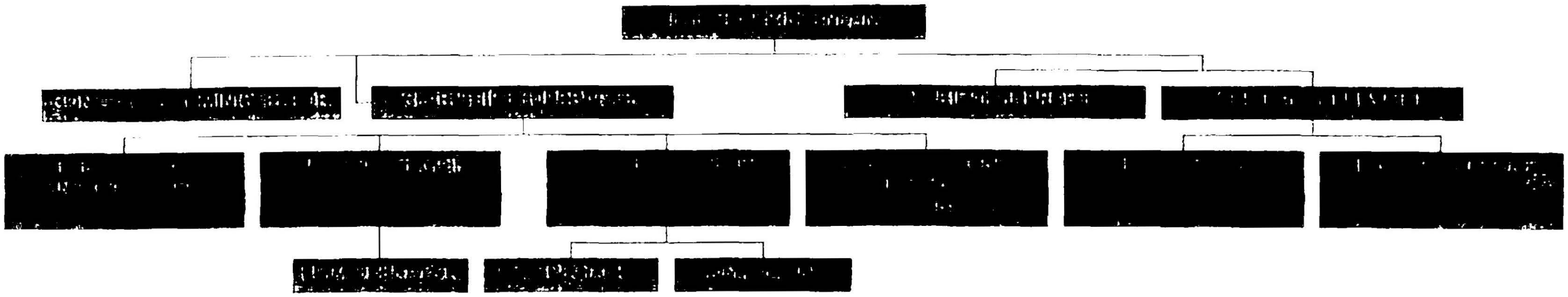
NOTE 1: Spacers numbered 1 to 4 from West End.

NOTE 2: East Spacer Displacement is Positive (+)
West Spacer Displacement is Negative (-)

NOTE 3: Displacement is in Millimeters

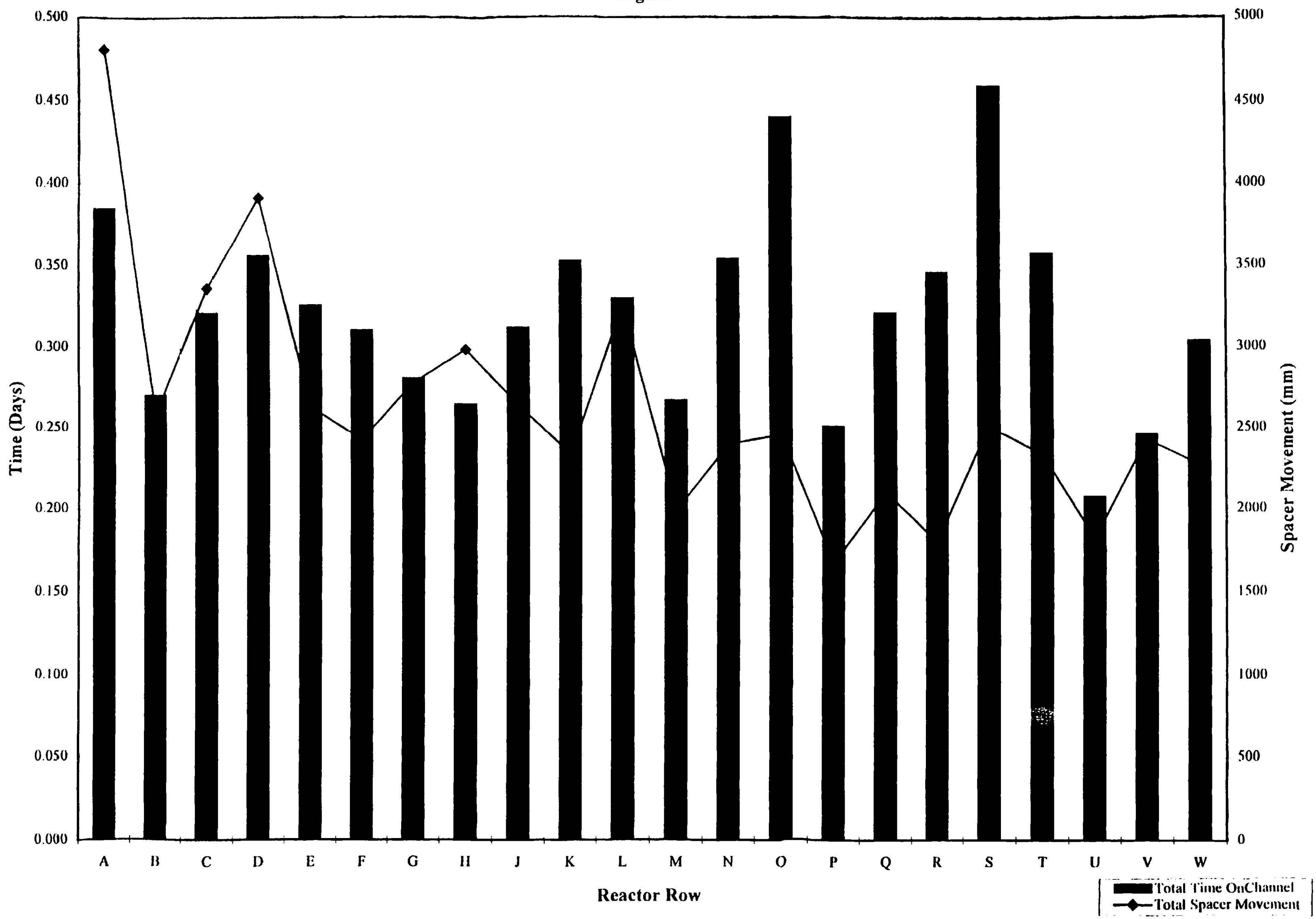
	SPACER 1 Δ FROM DESIGN	SPACER 2 Δ FROM DESIGN	SPACER 3 Δ FROM DESIGN	SPACER 4 Δ FROM DESIGN
EAST INLET	-97	-250	-146	-238
WEST INLET	-74	-121	-153	-310
TOTAL CHANNELS	-86	-186	-150	-274
TOTAL SPACER DISPLACEMENT IGNORING DIRECTION	672	694	844	946

SLAR PROJECT IMPLEMENTATION ORGANIZATION
(APRIL - OCTOBER 1995)
FIGURE 1

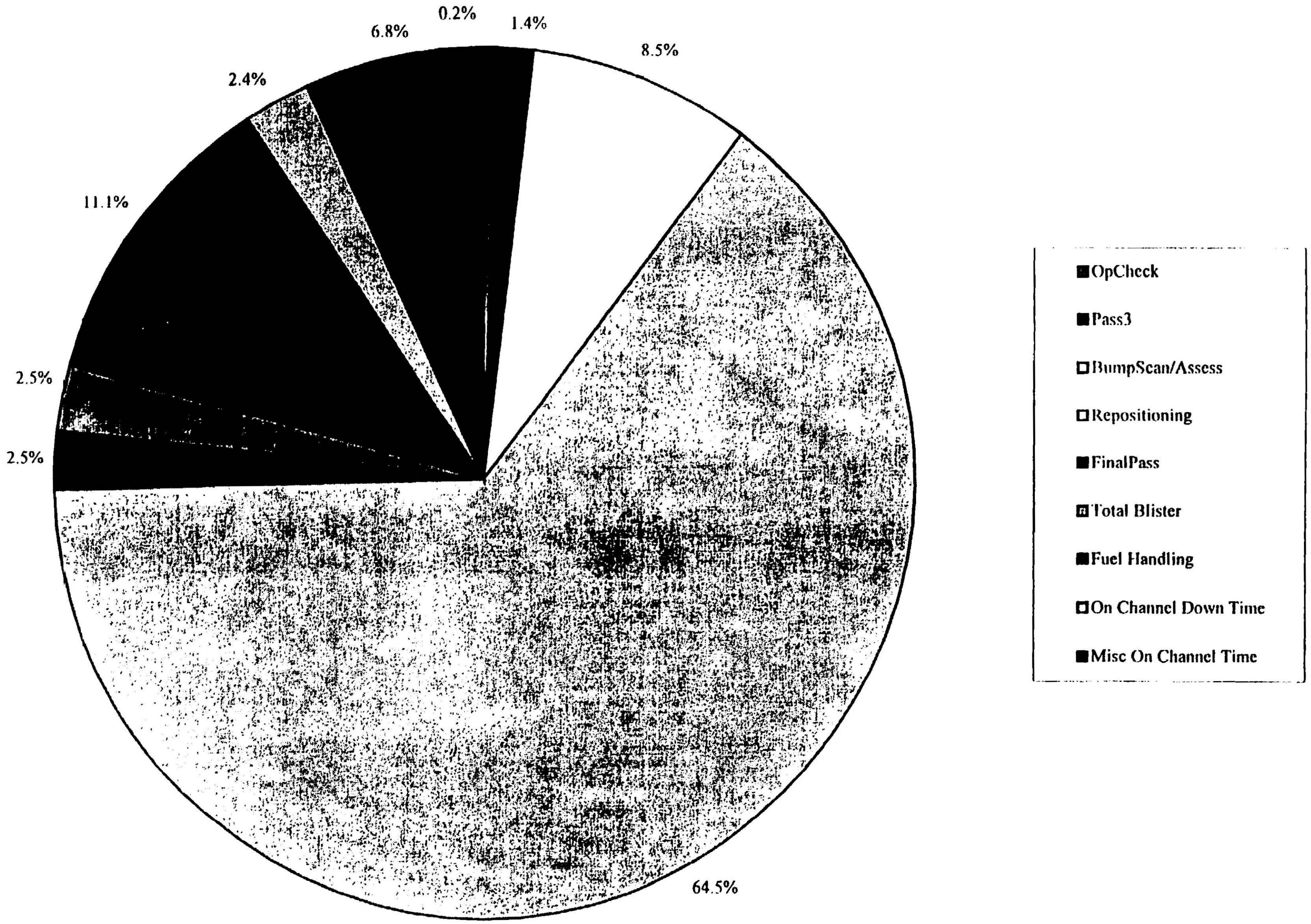


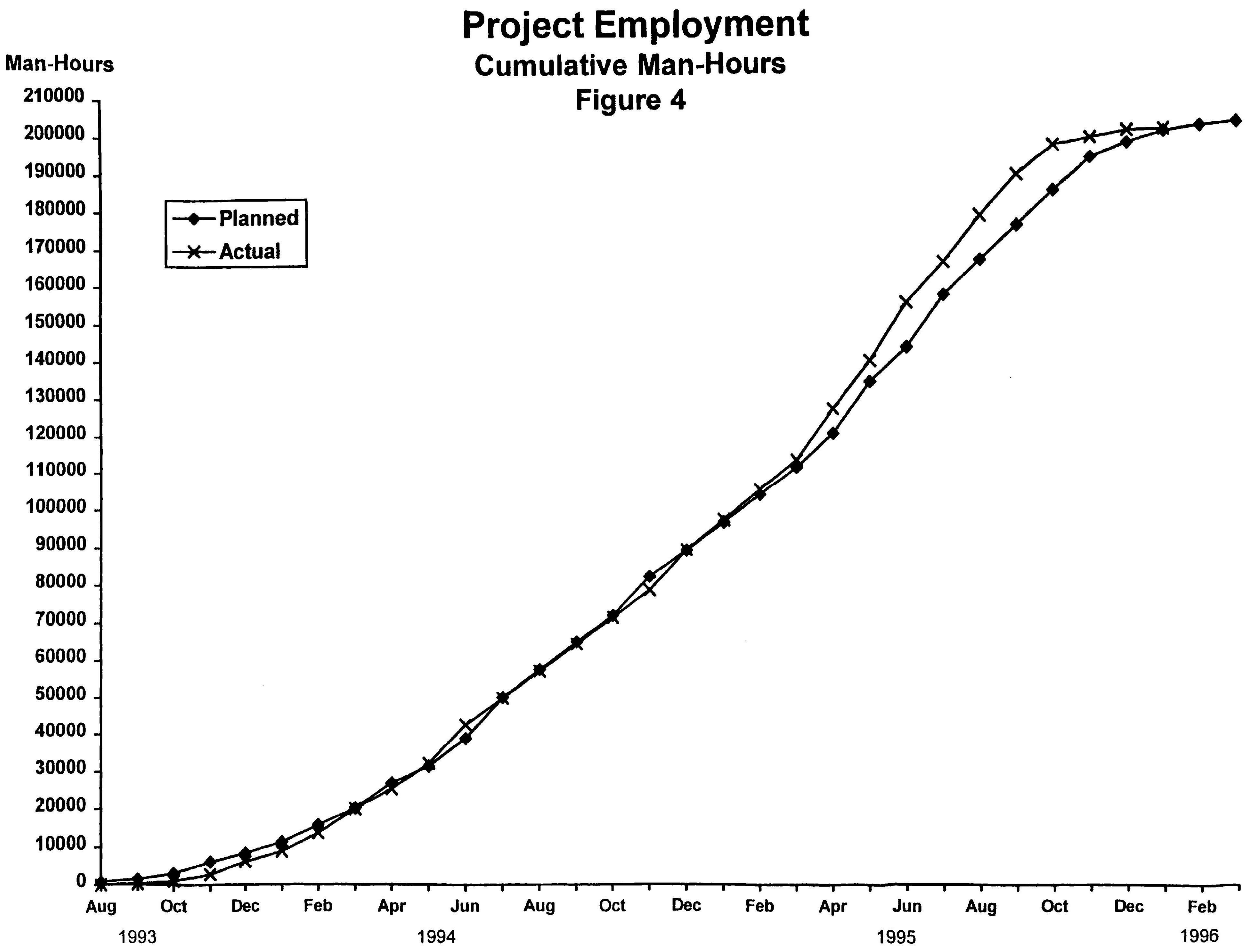
SLAR 1995 - Average Total Time on Channel and Average Spacer Movement Required to Meet the Target by Reactor Row

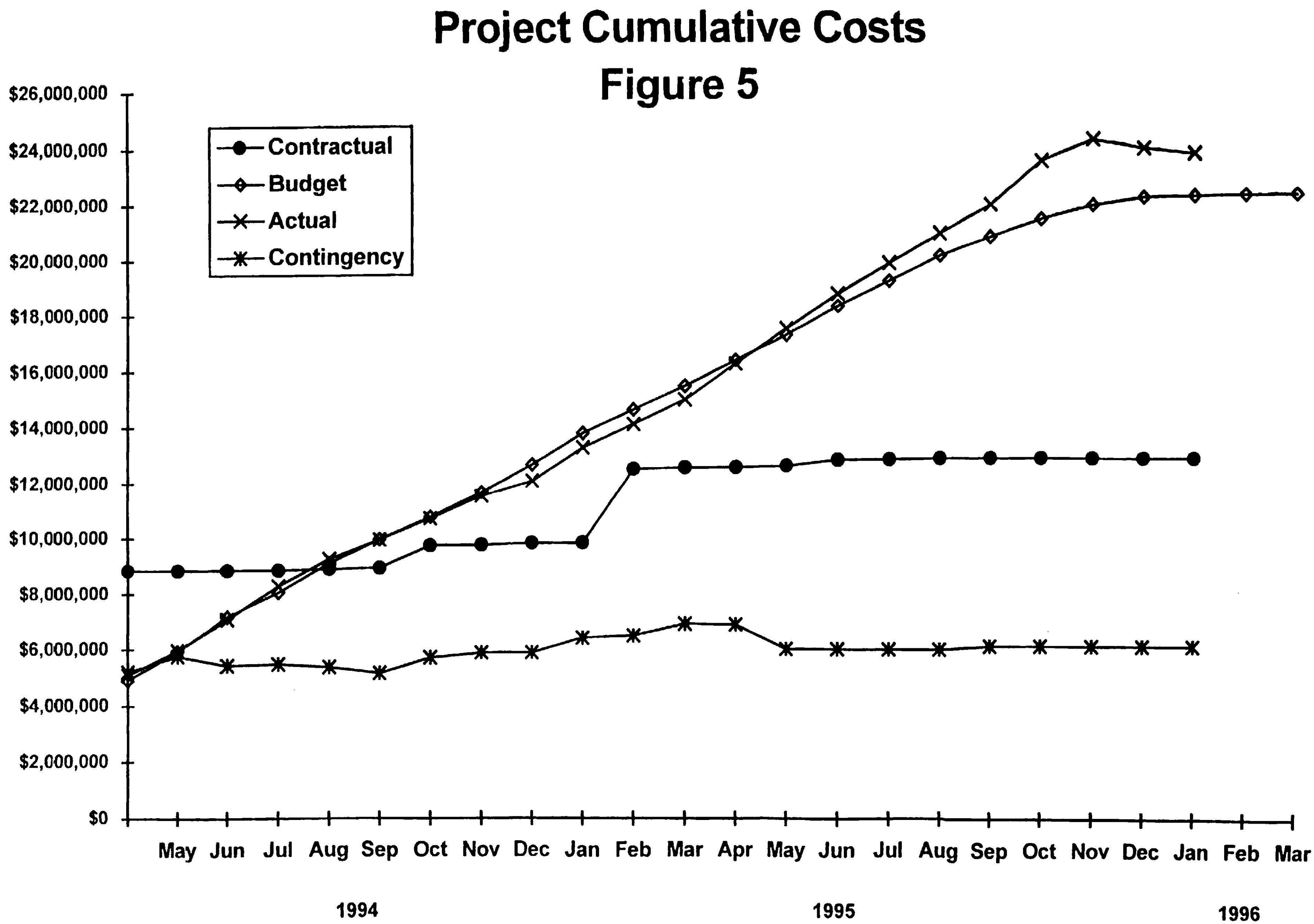
Figure 2



SLAR 1995 - On Channel Operation Times Expressed as a Percentage of the Total
Figure 3




Project Employment
Cumulative Man-Hours
Figure 4
Man-Hours
210000
200000
190000
180000
170000
160000
150000
140000
130000
120000
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Planned
Actual
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
1993
1994
1995
1996



Project Cumulative Costs
Figure 5
Contractual
Budget
Actual
Contingency
$26,000,000
$24,000,000
$22,000,000
$20,000,000
$18,000,000
$16,000,000
$14,000,000
$12,000,000
$10,000,000
$8,000,000
$6,000,000
$4,000,000
$2,000,000
$0
May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar
1994
1995
1996