SEQUOYAH NUCLEAR PLANT

RELIABILITY STUDY

MARCH 5, 1996

INTRODUCTION/BACKGROUND

The Site Vice President requested that an assessment be performed to evaluate why SQN's operating reliability has not improved over the last 18 months despite large investments in both personnel improvements and material condition of the operating units. The assessment was structured to have four teams develop data from different sources and cross validate information between teams. The first team conducted a series of group discussions with personnel in Operations, Maintenance, Technical Support, Component Engineering, and Nuclear Engineering to determine the latent hardware problems, review known hardware problems, and to determine why the current hardware problems have not been corrected by the normal processes. The second team conducted a detailed review of existing data sources relating to component performance to identify hardware problems and programmatic or organizational concerns. The third team performed an integrated systematic review of the heaters, drains, and vents system with respect to all aspects of the system performance to identify hardware problems and programmatic or organizational concerns relating to that system. The fourth team, lead by the Independent Review and Analysis Department, performed a common cause assessment on the more significant events which occurred in 1995 (and 1994 to a lesser degree) to determine the underlying causes for those events.

This report documents the results of the common themes that run through the individual team findings, documents specific findings, recommends corrective actions, and itemizes the hardware reliability issues. This report does not document the good performance or performance improvements noted during this assessment. Excellence in operations is the expected standard, anything less was highlighted in this report. Corrective actions are documented in SQ960393PER.

Attachment 1 list the hardware issues. Attachment 2 is the methodology and findings from the integrated systematic review of heaters, drains, and vents. Attachment 3 is the common cause results from Team 4. Attachment 4 is the charter for this assessment.

EXECUTIVE SUMMARY

The five programmatic findings described have either directly or indirectly affected operational reliability in the past and if left uncorrected will not only affect total MWe output annually, but will have an impact on SQN's SALP performance. The team recognized that actions are underway in some of the areas to correct performance but the team also recognized that, as a station, SQN does not have a good track record of following through on corrective actions, measuring incremental performance changes, and making necessary corrections.

- Station managers and supervisors have failed to consistently ensure that experienced, knowledgeable, and motivated personnel operate, maintain, and support plant operations to the expected standards at SQN. Employees, both supervisory and nonsupervisory, have not consistently assumed personal responsibility and been held accountable for achieving these standards during the course of daily work activities.

- Station managers and supervisors have failed to consistently work as one team with an overriding objective of excellence in operations. Excellence in operations includes the dependable, sustained operation of the units at full power with no operator challenges and a minimal need for on-line corrective maintenance. Inherent in this operational definition is the assumption of a nuclear safety first culture.

- Station managers and supervisors have failed to consistently ensure that equipment and personnel problems affecting unit reliability are properly corrected in a timely manner. Especially troublesome is the lack of follow through on identified corrective actions.

- The technical involvement of the engineering organizations in maintenance and operational activities has been ineffective in improving plant reliability and performance.

- Station managers and supervisors have failed to consistently manage organizational and process changes. This has resulted in essential activities being unassigned or not executed, and organizational roles and responsibilities not clearly communicated.

Twenty-three hardware issues were identified that either have affected operational reliability or have a high probability of affecting future reliability. Fourteen of the 23 have impacted plant operations and nine are high potentials for impacting future plant operations. Three of the nine have the real potential to cause a two unit trip or power reduction. A review of the draft 1995 reliability study identified 47 other hardware issues that have a lower probability of directly impacting full power operations. Recommendations for addressing the management and hardware issues are contained in the body of this report.

SQN COMPARISON TO DESIGN STANDARD, DS-M2.5.1

DESIGN FEATURE		DS-M2.5.1	SQN SYSTEM 6	COMMENT
Codes	Piping	ANSI B31.1	Same	
	Pr. Vessels	ASME VIII	Same	
	Heaters	HEI	Same	
	Pumps	HYD INST	Same	
Drains	Normal	1 to 2	Same	
		2 to 3 HDT	Same	
		3 HDT to 2 Condensate	Same	
		4 to 5	Same	
		5 to 6	Same	
		6 to 7 HDT	Same	
		7 HDT to 6 Condensate	Same	
Drains	Bypass	1 to 2	1 to Condenser	Better than DS.
		2 to Condenser	2 to 3 HDT (1)	Bad design, causes startup problems due to backpr sssue in 3 HDT preventing draining
		3 HDT to Condenser	Same	
		4 to Condenser	Same	
		5 to Condenser	5 to 6	
		6 to Condenser	6 to 7 HDT (3)	Causes heater string isolations due to inadequate static head to force drainage to 7 HDT pressure.
		7 HDT to Condenser	Same	
Vents	Flash	3 HDT to 3	Same	
		7 HDT to 7	Same	
Startup	at 40% Power	Start HDPs	35%	DCN M-06588-A
Transients	Stable Level Control and Venting	Turbine Trip	NA	Design info/calcs not available
		Loss FWH Section w/o Runback	Yes	Heater LCVs sized for this
		Loss 1 HDP w/o RB	Yes	Runback initiated if # 3 HDP flow less than 5500 gpm, no runback for # 7 HDPs
		Loss 1 MFP w/o RB	No (2)	Only two 50% capacity MFPs, operating experience indicates only about 65% per MFP
		Loss all HDPs w/RB	Yes	Both 3 HDT & 7 HDT bypasses sized for full flow
		Loss 1 HDP LCV	Yes	Both 3 HDT & 7 HDT bypasses sized for full flow
		MSR Abnormal/Test Opn	NA	Design info/calcs not available
Drain Tanks	Min. Capacity @ NWL	1 min. @ 105% NSSS	NA	Design info/calcs not available
	Flash Vent Capacity	100% Flashing @ 105% NSSS with ΔP=ΔH-3psi	NA	Design info/calcs not available
	Static Head @ NWL	Drain to Cond @ ΔP=0	NA	Design info/calcs not available
Drain Pumps	All Pumps Sized For	100% Load & Max Demin ΔP	NA	Design info/calcs not available
		105% Load & Min Demin ΔP	NA	Design info/calcs not available
	2 #3 & 1 #7 HDPs Sized For	40-60% Load & Min Demin ΔP	NA	Design info/calcs not available
LCVs	Heater	Full Open @ 150% Full Load Flow	Same	Max flow considers one string of heaters bypassed
	3 HDT	Stable Opn. 40-105% Load	Yes	DCN M-06588-A
	7 HDT	Stable Opn 25-105% Load	Yes	Min flow = 25% Heat Bal & Max = 150% full load
	3 HDT Bypass	Total Drain @ 50% Load & Stable @ 10% Load	Better	Total Drain @ 100% load
	7 HDT Bypass	Not Specified	Full Bypass	Sized for total bypass @ 100% load, with no pumps running
Instrumentation	Minimum	Pump Suction Temperatures	No	Pump discharge temperatures are adequate
		Suction & Discharge Pressures	Yes	
		Temperatures in all Drain Lines	Yes	No HDT drain line temperatures
		FWH Channel Relief Temps	No	Not required, discharge to tunnel will be obvious
		3 HDP & 7 HDP Discharge Flows	No (4)	Total flow not individual pumps, #7 HDT pumps only input to plant computer (P250)
	MCR indication	Pump Motor Current	Yes	
		HDP Discharge Pressures	No	Input to plant computer (P250)
		All HTR Levels (controlled)	No	Abnormal alarm only, no high or low specific indication
		HTR High Levels (uncontrolled)	NA	Not Applicable
		LCV & Isol Valve Status	No	None except bypass valve lights
		Open Bypass Alarms	3 HDT only	R/G lights for other bypasses

NOTE: The most significant design differences are identified with a recommended priority number shown in parentheses in column 4 above.

Contacts for Heater Drains and Vent system:

Comparison of Heater Drains and Vent system to other plants:

Plant	Sequoyah	Browns Ferry	Zion	Callaway	D. C. Cook	McGuire
Startup Year	1980	1971	1973	1984	1975	198[illegible]
NSSS	W	GE	W	W	W	W
Turbine/Generator	W	GE	GE	GE	W,BB	W
# of FW Heaters	21	18	18	18	12	21
FW Heaters w/ bypass to condenser	6 of 21	6 of 18	18 of 18	18 of 18	8 of 12	21 of 21
Heater level controller redundancy	no	no	yes	yes	yes	yes
HDT / pump forward systems	double	none	single	single	single	double
# of condensate & feedwater pumps (running)	11	9	5	5	6	6
pump redundancy	no	no	yes	no	yes (exc MFP)	yes (exc MFP)
MSR reheat stages	2	0	1	2	2	2
separate MFPT Condenser	yes	no	no	no	yes (CCW cooled)	yes (CCW cooled)
WR backlog / unit	90	50	50	40	20	25
contact	Ken Hurt	Joe Wheeler	Rich Harwood	Paul Hobbs	Joel Jinesse	Phil Goodman
telephone	423-843-7754	205-729-3618	847-746-2084 ext 2313	314-676-8310	616-465-5901	704-875-4683

Notes:

DC Cook: 2 strings of heaters, ride all heater during startup,

Callaway: ride all heaters during startup, 3 strings of 4 LP htrs & 2 strings of 3 HP htrs, only 2 sets of cond/FW pumps, use magnetic S/G & level switches (work well),

FINDING 1:

Station managers and supervisors have failed to consistently ensure that experienced, knowledgeable, and motivated personnel operate, maintain, and support plant operations to the expected standards at SQN. Employees, both supervisory and nonsupervisory, have not consistently assumed personal responsibility and been held accountable for achieving these standards during the course of daily work activities.

BASIS:

- The common cause assessment of 124 level A and B PERs issued during 1994 and 1995 indicated that, as a station, our personnel caused knowledge based errors at twice the mature station average.
- Independent assessments of the site training programs have repeatedly found poor management involvement in and ownership of training.
- The PER common cause assessment concluded that the knowledge and experience of on-shift operations crews, relative to normal plant operation, has declined in recent years because of the influx of new operations personnel and a reduction in systems training and hands-on job training.
- Secondary system transients and startup delays have been caused by Operations personnel having a less than adequate understanding of plant system operations or failing to verify and validate information. Examples include the water hammer in the extraction steam system, "shocking" the RCP seals, opening the MSIVs against high delta P, response to feedwater heater string isolations when placing heaters in-service, and valving in the MSRs.
- The common cause assessment concluded that (1) supervisors do not provide the necessary coaching or accountability, (2) craftsmen have inadequate skills or knowledge for some tasks, and, (3) craftsmen do not fully understand or apply self-checking and questioning attitude techniques (STAR and QV&V). These deficiencies have resulted in improper/incomplete repairs, causing outage delays and system transients, challenges to system operation, and startup delays. Examples include generator cooling flange leaks, stator water cooling temperature switch installation, feedwater regulator valve positioner air supply line failure, condensate booster pump alignment problems, EHC setpoint change, heater drain tank pump casing drain leakage, water box manway gasket leaks.
- Interviews with station personnel indicated there is a strong perception that, across the board, (Operations, Maintenance, Engineering, and management) knowledge of unit operations has deteriorated.

CORRECTIVE ACTIONS:

	Responsibility/ Due Date
1. Site Vice President, Plant Manager, Engineering and Materials Manager, and Business and Work Performance Manager review findings of this report with their line supervisors and obtain a personal commitment from each that they are accountable, personally, for the actions of their employees and they will be held accountable for their subordinates performance. Specifically, supervisors are responsible for ensuring that employees possess demonstrated knowledge and experience using the proper tools and procedures to perform unsupervised tasks at SQN, and that the expectation of the performance standards are clearly stated to the employee just prior to performance of the task. Contracts requiring signatures will be cascaded down by March 15, 1996.	All March 15, 1996
2. The Operations Manager and Operations line supervisors will ensure that Operations personnel with demonstrated knowledge and experience will perform or supervise the performance of any activity described in the Sensitive Activities Manual. The Operations Manager will further ensure that Operations training, retraining, and performance monitoring programs gain, maintain, and measure knowledge and experience to reduce <u>knowledge</u> based errors by 70% by the end of the first quarter of calendar year 1997.	Greg Enterline March 31, 1997
Operations Manager will develop a balance of plant requalification training program incorporating systems and/or component engineers utilization.	Greg Enterline April 1, 1996
Operations Manager will revise the Sensitive Activities Manual to focus on unit reliability improvement and to proceduralize supervisor responsibility.	Greg Enterline March 22, 1996
3. The Maintenance Manager and Maintenance line supervisor will ensure that craft personnel with demonstrated knowledge and experience will perform or supervise the performance of any activity described in the Sensitive Activities Manual. The Maintenance Manager will further ensure that maintenance training, retraining, and performance monitoring programs gain, maintain, and measure knowledge and experience to reduce the <u>knowledge</u> and <u>rule</u> based error percentage by 30%.	Dave Brock March 31, 1997
Retrain Maintenance supervisors and craftsmen in STAR and QV&V by start of U2C7.	Dave Brock Start of U2C7
Increase the amount and quality of field supervision.	Complete
4. Reissue the SQN Personnel Accountability Guidelines and utilize the Guidelines, to hold all employees and line supervisors up to and including the department managers accountable for human performance errors.	Bob Adney March 7, 1996

FINDING 2:

Station managers and supervisors have failed to consistently work as one team with an overriding objective of excellence in operations. Excellence in operations includes the dependable, sustained operation of the units at full power with no operator challenges and a minimal need for on-line corrective maintenance. Inherent in this operational definition is the assumption of a nuclear safety first culture.

BASIS:

- Department budgets and personal resource allocations are not developed to target excellence in operations. A review of the capital budgets over the last three years found a large fraction of the budget was allocated to nonunit reliability improvement projects. Examples include: Security, Bomb Barriers, Fire Protection, Chemistry Upgrade, Civil Upgrade, and Drawing and other Engineering reconciliation upgrades. The review also indicated some unit reliability projects have been routinely deferred because the economic rate of returns were too low. A review of the operating budget found the budget was primarily based on covering payrolls and that task budgets focused on individual department needs rather than supporting specific plant reliability needs.

- The 12 Week Rolling Schedule is the primary method used to prioritize, plan, review, and implement routine operational, maintenance, and testing activities. This process, by design, is SQN's tool to optimize the one team concept. The PER reviews, vertical slice of HD&V, and employee interviews, indicate that the site departments are not working as a team to make the 12 Week Rolling Schedule a success. Lack of participation, conflicting priorities, and inconsistent understanding of roles and responsibilities are contributors to the less than optimum daily schedule performance.

- The design impact review process is structured to obtain departmental input to a plant modification prior to implementation. PER reviews and personnel interviews provided numerous examples of the failure of one or more team members to support the whole team effort.

CORRECTIVE ACTIONS:

	Responsibility/ Due Date
1. Reestablish focus areas and adhere to them • Capacity factor improvement and SALP improvement drivers should be number 1. Nuclear safety is always the fundamental standard • U2C7 outage should be a close second Problem identification and resolution need the next highest priority since it is the feedback loop to improve on 1 and 2 • Fiscal responsibility and selective process improvement should come next	Jim Baumstark/ Frank Fink March 15, 1996
Restructure the PRM and/or MRC to evaluate performance in the focus areas.	Jim Baumstark/ Frank Fink April 13, 1996

2. Reestablish a plan-of-the-day type meeting chaired by the Plant Manager, Assistant Plant Manager, or Operations Manager and attended by plant support team members with the focus on plant operations. Daily assignments should be made at the meeting, with owner, deliverable, and performance dates established. The code of conduct (standards, expectations, responsibilities, ownership, authority, commitment, and accountability) should be the framework to cause change. Daily scheduling should be reviewed similar to an outage meeting. — Jim Baumstark, Complete

3. Prioritize the FY 1997 Capital and O&M budget by the focus areas and develop a task based budget to support those priorities. Reflect this philosophy in the SQN FY 1997 Business Plan. Supervisors should ensure that resources are not expended on any task that does not support SQN focus areas. — Frank Fink, April 13, 1996

4. Develop a site material condition report which consolidates prioritized hardware focus areas. Include in the report maintenance WR indicators, operator distractions (e.g., work arounds, lit annunciators) system health, maintenance rule performance, and unit generator/capacity factor performance. — Frank Fink, May 1, 1996

FINDING 3:

Station managers and supervisors have failed to consistently ensure that equipment and personnel problems affecting unit reliability are corrected properly in a timely manner. Especially troublesome is the lack of follow through on identified corrective actions.

BASIS:

- Ineffective root cause investigations, inadequate recurrence control, untimely corrective actions, and problem ownership has lead to numerous repeat events (stator cooling water temperature switch, bus duct gasket, exciter problems, PSRV leakages, feedwater heater string isolations, CCW pump trips, main bank transformers trips, etc.). A collective review of lost-capacity events from 1993 to the present indicate more than half were either repeat events or had known precursors.

- The lack of involvement and oversight of management and site personnel in vendor and Customer Group support activities has resulted in equipment performance problems and plant capacity losses (voltage regulator analysis, EHC power supply setpoint adjustments, exciter repairs, bent thermocouple column, PMG ground straps, switchyard breakers, transformers and relays, Westinghouse work on EHC RH/TV closure).

- Previous evaluation actions and program recommendations to improve site and plant performance have not been consistently followed through on by the management team. Specifically, some recommendations from previous reliability efforts remain unimplemented after several years. Predictive and preventive maintenance actions and recommended modifications are still in some cases in the planning stages.

CORRECTIVE ACTIONS:

	Responsibility/ Due Date
1. Reissue incomplete corrective actions identified in previous reliability efforts (May 17, 1993, SWEC BOP Design Study; June 4, 1993, SQN Secondary Plant Reliability Study; and 1995 Draft Reliability Team Report)	Bill Lagergren March 8, 1996
Provide the reason for not implementing the action in writing to the Plant Manager or provide an action plan for implementation.	Individual Corrective Action Owners March 22, 1996
2. Revise and update quarterly the SQN Business Plan to include specific reliability improvement corrective actions. Each corrective action will include an owner with due date. Department managers performance appraisals will be adjusted quarterly to reflect performance against these due dates. The actions will: • address root cause(s) • be cost effective • can be implemented in a timely manner	Frank Fink March 29, 1996
3. Revise SSP 3.4 to include personnel qualification requirements, for performing equipment root cause analysis.	Jim Baumstark March 15, 1996
• Train individuals im problem solving techniques	Jim Baumstark July 15, 1996
4. Review and revise Customer Group interface agreements to improve equipment performance problems and reduce plant capacity factor losses.	Dave Brock July 19, 1996
5. Review and revise Partners In Performance agreements to improve equipment performance problems and plant capacity factor losses.	Dave Brock July 19, 1996

FINDING 4:

The technical involvement of the engineering organizations in maintenance and operational activities has been ineffective in improving plant reliability and performance.

- Interviews with numerous Operations, Maintenance, Radcon/Chemistry, and Scheduling personnel indicate a dissatisfaction with the level of nonemergency support from the engineering groups, both in day-to-day support and in the anticipatory look ahead reliability improvement area.

- Based on plant operational performance, insufficient engineering resources are focused on activities which contribute to future plant performance and operating improvements. For example, little time is being allocated to address impending equipment obsolescence and aging, adequacy of spare parts, understanding and minimizing plant hardware vulnerabilities, analyzing corrective maintenance and repetitive problems to adjust PMs. Additionally, technical oversight to vendors has been insufficient to ensure component reliability.

- Examples where a proactive look ahead or close oversight of vendor task would have prevented past MW losses include extraction piping failures, main steam check valve failures, numerous excitor and voltage regulator failures, pressurizer safety valve leakage, condenser ugprades, numerous turbine control failures, reactor coolant pump motor and seal failures, steam dump failures, and water intrusion into control air system.

- Examples of some areas where actions are underway that are correcting future reliability issues (to date have not affected MW output) include MSIV upgrades, integrated computer, feedwater chemical addition efforts, and CCW bearing lube water upgrades.

- The SQN process (TFARs) for factoring corrective maintenance experience into the preventive maintenance program has been ineffective. Of over 5,000 trend reports identified since 1991, only 40 corrective action plans were developed (it should be noted that some trend reports were dispositioned by reference to existing corrective action plans). In general, the validated conditions were dispositioned by one-time corrective maintenance or initiating a MIL issue. In only a few cases was the PM program even reviewed or modified.

- A review of the actual schedule performance and the schedule development for the T-6 to the T-0 schedule indicates that a lack of engineering involvement in the maintenance planning and scheduling and materials procurement processes has resulted in prolonged troubleshooting and diversion of maintenance resources. Examples: approximately 20% of MIG work orders are closed with no problems found; an average of 16 work requests are removed from the schedule weekly for lack of materials in the T-6 to T-0 schedule; participation of engineering personnel in scheduling meetings is marginal.

- Lack of engineering involvement in corrective maintenance field activities has in some cases resulted in poor cause analysis, delayed problem resolution, and has allowed repeat problems. This lack of involvement was especially problematic in systems where Sequoyah does not or did not possess technical knowledge comparable to either a vendor or to a service provider such as the Customer Group. Examples include: RCP seals, CCW pump motors, main bank transformers, common service station transformers, switchyard breakers, EHC systems, main generator and vendor supplied support systems and components, rod control systems, and reactor trip breakers.

CORRECTIVE ACTIONS:

	Responsibility/ Due Date
1. Reassess the engineering involvement in and support of maintenance planning, maintenance performance, maintenance problems analysis, trending and data analysis to adjust the preventive and predictive maintenance program.	Marcia Cooper/ Mike Cooper/ Mark Burzynski August 1, 1996

Revisit/define management expectations for reliability, specifically the responsibilities and interfaces of TSS, CE, Scheduling, Maintenance, Outage Management, Project Management, Operations, and Engineering and Materials. (Place special emphasis on those programs or organizations that have undergone changes in scope and responsibilities in the last three years and do not limit the review to only plant reliability responsibilities.) Include the following:

- depth of site experience
- utilization of operating experience
- trending
- proactiveness
- total system overview responsibilities
- PMs
- component failure and aging data
- equipment obsolescence
- parts and materials
- sensitive equipment.(WR/WO reviews)
- vendor manuals
- thermal performance

In the interim, a number of actions to improve engineering effectiveness have been taken and are ongoing. These include establishment of engineering unit interface supervisors to focus day-to-day engineering support; conduct of ongoing engineering/customer interface meetings to establish agreement on responsibilities and priorities; Technical Support reevaluation and establishment of Mission, Values, Roles, and Responsibilities; increased resource focus on and reinforcement of predictive/preventive activities; development of an Equipment Root Cause Program including additional root cause training and management oversight; improved formality and review of engineering communication (i.e., recommendations, action plans, operability evaluations, etc.); and establishment of more specific performance goals tied to plant reliability.

2. Establish a U2C7 hit team to evaluate knowledge based errors specific to reliability improvement systems. The team will assign actions to the Maintenance Manager to provide support in questionable areas. — Larry Bryant, April 1, 1996

3. Perform an additional review of the trip snesitive systems to ensure that any component or subcomponent that is at or near end of life or has been exposed to adverse operating conditions (overvoltage, heat, etc.) be replaced. Additionally, any component or subcomponent that has demonstrated past reliability problems should be replaced. Recommended systems include: — Marcia Cooper, prior to U2C7
   - Main Steam System
   - Feedwater and Condensate Systems
   - Extraction and Heaters, Drains, and Vents Systems
   - Main Turbine Lube Oil System
   - Condenser Circulating Water System
   - Control Air System
   - Stator Cooling Water and Lube Oil Systems
   - Main Feed Pump Control System
   - Electro Hydraulic Control System
   - Main Generator and Exciter
   - Electrical Distribution Systems
   - Main Bank and CSS Transformer and Other Switchyard Components and Relays

FINDING 5:

Station managers and supervisors have failed to consistently manage organizational and process changes. This has resulted in essential activities being unassigned, not executed, and organizational roles and responsibilities not clearly communicated.

BASIS:

- Following an organizational realignment that moved engineers out of Maintenance, the responsibility for spare part identification and inventory maintenance, and PM program technical ownership was not clearly reassigned.

- The assignment of new Operations personnel to shift supervisory positions did not adequately assess the potential impact of the lack of "in-plant" operating experience on plant and personnel performance.

- During outages, experienced field supervision of maintenance activities is significantly reduced. Experienced craft personnel are elevated to temporary foreman status for temporary craft hired for maintenance support. The net result is an overall drop in craft and supervisory experience.

- Transition of the obsolete/aging equipment program into the MIL system and the loss of the program owner resulted in an ineffective obsolescence program.

- A number of programs and processes have changed over the last 18 months to reduce cost and improve productivity. With each change a number of PERs have been generated because of failure on our part to implement the new processes as designed. The transition process is not being managed effectively (12-week scheduling process, clearance process, budgeting process, maintenance performing mods process, etc.).

- The management team is allowing peripheral, nonplant reliability issues to take up a large fraction of their time (process standardization, 360 feedback, responding to outside assessments, recovery efforts from personnel and/or equipment problems, nonproductive meetings, or other activities that are outside daily plant operations or site focus areas).

CORRECTIVE ACTIONS:

	Responsibility/ Due Date
1. Provide a management training course in implementing change.	Mark Shephard June 15, 1996

Note: Other corrective actions for Finding 5 are addressed in Findings 1 through 4.

ATTACHMENT 1

Hardware Issues

1. Numerous heater string isolations, loss of feedwater flow and subsequent reactor trips have occurred due to the inability of the No. 2 feedwater heaters to "pump up hill" to the No. 3 heater drain tank at low power levels.
    - Design FY 1997, 1998; Implementation U2C8, U1C9
    - Owner: Darrell Widner, Project Management

2. In 1992 and again in 1995, electrical faults in the switchyard resulted in multiple condenser circulation water pumps tripping. The ensuing loss of condenser vacuum has resulted in turbine and reactor trips.
    - Study complete; Design FY 1996; Unit 1 implementation by end of U1C8 (pump 1C already complete); Unit 2 implementation is complete
    - Owner: Donna Wilson, Project Management

3. Yarway Valves for the heater drain tank pumps and condensate pumps are a continual source of problems due to the valves leaking through. These valves have been rebuilt with vendor supplied parts under vendor supervision. Leakage causes lost megawatts and possible pipe failure due to vibration. The condensate booster pump recirc line is currently isolated on Unit 1.
    - Design FY 1997, 1998; Implementation U2C8, U1C9
    - Owner: John McPherson, Project Management

4. The main feed pump recirculation control valve is manually isolated due to leakage and the resulting flashing and pipe erosion down stream of the valve. This item is also a major Operator workaround. Also, valve 3-70 is experiencing hi-vibration during startup after the installation of the breakdown orifices to resolve the flashing problem.
    - Study FY 1997; Design FY 1997, 1998; Implementation U2C8, U1C9
    - Owner: Ross Malone, Project Management

5. Numerous turbine/reactor trips have occurred due to spurious main transformer sudden pressure relay and gas operated relay actuations. Although the most recent trip has been isolated to inappropriate maintenance activities, multiple events with multiple "fixes" have been tried over the last 10 years but events continue to occur.
    - Study underway; cause analysis complete; fix has been identified; management presentation planned for 4/10/96. Completed
    - Owner: Frank Cuzzort, Technical Support
    - Review switchyard design basis
    - Owner: Frank Cuzzort, Technical Support - Complete 9/30/96

6. The cuno filter for the seal oil system is a potential single point failure. Clogging of the filter has nearly resulted in loss of hydrogen two times within the last three years. Loss of hydrogen would result in hydrogen fires at the main generator shaft seals due to seal loss. Also, the present filter design does not allow for maintenance activity on the filter while the generator is pressurized with hydrogen. Redundant filters have been installed at other plants to eliminate this failure potential.
    - Design complete; Implementation U1C8 (Unit 2 complete U2C7)
    - Owner: Donna Wilson, Project Management

7. The No. 7 heater drain tank (HDT) has experienced difficulty in optimum performance, resulting in plant perturbations including reactor trips. Problems: no tank flow indications in the main control room (MCR) to allow early detection of problems; poor performance and obsolescence of the 6-190A spillover valve.
    - Provide No. 7 HDT Flow in the MCR
    - Design FY 1997, 1998; Impl U2C8, U1C9
    - Owner: Donna Wilson, Proj Mgmt

    No. 7 HDT Optimization
    Design FY 1998; Impl U1C9, U2C9
    Owner: Donna Wilson, Proj Mgmt

8. Sequoyah has a generator trip for generator power imbalance protection which Westinghouse states is no longer needed. The circuit has caused a turbine trip when a circuit component failure and resulted in the intercept valves closing. This circuit has been de-activated on Unit 1.
    - Design complete; Implementation completed U2C7 - everything complete
    - Owner: Ron Gladney and Roswell Schnur, Technical Support

9. The Sequoyah WTA voltage regulator has aging and obsolete circuit board components. Electronic subcomponents on the existing cards and modules are nearing (in some cases) end of life.
    - Design FY 1997, 1998; Implementation U2C8, U1C9
    - Owner: Ross Malone, Project Management

10. The feedwater heater level control valves and positioners are obsolete and unreliable.
    - Study FY 1997
    - Owner: Doug Craven, Ops Support, Nuclear Engineering/Donna Wilson, Proj Mgmt

11. Condensate booster pump (CBP) suction pressure switches have water leakage into junction box; causing repetitive switch failures and calibration problems. Since this switch is part of the CBP trip circuit, an inoperable switch could lead to pump failure and condensate swings due to spurious pump tripping.
    - Study FY 1997
    - Owner: Doug Craven, Nuclear Engineering-OSG/Donna Wilson, Proj Mgmt

12. The main feed pump and turbine vibration monitoring is nonfunctional and obsolete. Advance warning for eminent equipment problems is inadequate.
    - Design in impact review; Implementation U2 in progress, U1C8
    - Owner: Bob O'Bannon, Maintenance

13. Transients in the steam seal system have contributed to several startup delays. Repeat problems include the inability for the steam seal system spill over valve and the steam seal control valve to operate smoothly, causing excessive amounts of steam flow in spill over headers; undersized motor operators on FCVs; no control feedback for PCVs.
    - Repl Motor Operators 1&2-FCV-47-180, 181
    - Design FY 1997, Impl U2C8, U1C9
    - Owner: Donna Wilson, Proj Mgmt

    Add Position 1&2-PCV-47-189
    Design FY 1997, Impl U2C8, U1C9
    Owner: Donna Wilson, Proj Mgmt

14. The station air compressors are unreliable and are high maintenance items.
    - Study complete; Design FY 1997, Implementation FY 1997, 1998
    - Owner: Darrell Widner, Project Management

15. Some of the electro-hydraulic control cabinet circuit boards electronic subcomponents are approaching end of life.
    - Initiate WR's; Implementation U1C8, U2C8
    - Owner: Roswell Schnur, Technical Support

16. Multiple single point failures exists in the balance of plant, especially in the main feed pump (MFP) controls. Many utilities (Callaway, South Texas, Calvert Clifts, et. al) have designed redundancy into the MFP.
    - Design FY 1999; Implementation U1C10, U2C10
    - Owner: John McPherson, Project Management

17. The filtered water source for the normal bearing lube water pumps is the otherwise abandoned MWPT sandfilters in the old water plant in the turbine building. These filters have failed several times causing draining of the clear well tanks and use of the emergency pump to supply bearing lube water. A failure of the emergency pumps in conjunction with draining of the clearwell tanks could effect operation of the CCW pumps and force a dual unit shutdown.
    - Study complete; Design and Implementation FY 1997
    - Owner: Ross Malone, Project Management

18. Modifications has been made to the PSRV tailpipe hangers to minimize nozzle loads, to pressurizer cubicle ventilation and to PSRV trim. The PSRVs still periodically exhibit leakage during pressurization to NOTP, resulting in startup delays.
    - Study in progress; Design FY 1996, 1997; Implementation U1C8, U2C8
    - Owner: Ron Skelton, Project Management

19. Recent failure of RCP seals and motors have resulted in startup delays and forced outages.
    - Common cause analysis has been completed. Corrective action documents have been generated and dates for corrective actions implementation are being developed.
    - Owner: Ed Barels, Component Engineering/Mike Lorek, Nuclear Engineering

20. Preventative maintenance techniques for the main generator exciter has been inadequate to assess degradation and enable corrective action to be taken prior to equipment failure.
    - Completed as identified in SQ952333PER.
    - Owner: Gary Buchanan, Technical Support

21. Due to the high voltage from the batteries, numerous BOP relays are exposed to the 270 V potentially leading to degradation and premature failure. In addition, the 125 V system has similar high voltage.
    - Technical support reviewing potential for damaged components. Scheduled to complete by 11/22/96.
    - Owner: Gary Buchanan, Technical Support
    - Implementation station battery project - in progress, complete FY 96
    - Owner: Ross Malone

22. The 71L3 relay for the No. 3 HDT NPSH trip is normally energized. Failure of this relay would cause all 3 No. 3 HDT pumps to trip and result in a unit runback or trip due to the resulting transient.
    - WRs initiated and relays replaced in 1993. Recent review indicates relays are still reliable and rated for continous duty.
    - Owner: Ken Hurt, Technical Support

23. High temperatures in the turbine building during the summer leads to premature equipment aging. Also consider sensitive electronics adjacent to steam lines.
    - Systems Engineers have started a review for sensitive components. Scheduled to complete 11/22/96 (both units).
    - Owner: Mark Skarzinski, Technical Support Manager

ATTACHMENT 2

Attachment 2

Project Plan for Integrated Sequoyah Capacity Factor Improvement Assessment Investigation Team 3 System 6 (Heaters Drains and Vents) Vertical Slice

Vertical Slice Focus Areas:

A. System 6 Design
- System Description/Design Criteria Document
- FSAR Description
- Drawings
- Vendor Information
- Component Specifications
- Calculations
- Configuration Control
- Design Limits and Operating Requirements
- Problem Reports
- SQN Comparison to Design Standard, DS-M2.5.1
- SQN Comparison to Other Sites

B. Material Condition of System 6
- TACFs
- Current Open WR/WO Evaluation
- Labeling
- Obsolete and Aging Equipment
- Maintenance Procedures
- Open Modifications
- U1 Downpower/Trip System Comparison for 1992, 93, 94,& 95
- WR/WO System Comparison for 1995 and Complexity Relationship
- System 6 Open Work Item History for Past ~18 Months
- System 6 Open Work Item Evaluation for 1995
- Site Maintenance Backlog for Past 6 Months
- Site Non-Outage CM WR's/WO's By Maintenance Rule
- Site Non-Outage CM WR's/WO's By Age
- System 6 Problems Between 1-1-94 and 12-31-95 Based On SQN Unit 1 & 2 Operational Summaries

C. Programmatic Issues Associated With System 6
- WR Priority/12 Week Schedule
- Modification Priority System
- Operating Experience
- Review of SSP-8.50, Conduct of Technical Support
- Configuration Check of Flow Prints

D. Organizational Involvement With System 6
- Operations
- Engineering
- Technical Support
- Component Engineering
- Maintenance
- Planning

E. Quality of Procedures/Drawings Associated With System 6

F. PM Adequacy of System 6
- PM Historical Perspective
- Scheduling
- Technical Input
- System 6 PM Health
- RCM Program
- Maintenance Procedures

G. Parts Adequacy for System 6
- System 6 Parts Availability Problem Survey
- Who Is Responsible For Parts Survey
- System 6 TIIC Random Sample Survey
- WRs/WOs Removed During Schedule Development Process Due To Material Problems

H. Operations Related Items Associated With System 6
- Operator Training
- System Operating Procedures and Prints
- Control Room Deficiencies
- Work Arounds
- Sensitive Equipment Issues
- Special Information/Knowledge Required to Operate System
- System Abuse Caused by Operating Philosophy
- Complexity Relationship Between SQN and Other Plants

I. Previous BOP Reliability Studies and Associated Recommendations
- May 17, 1993 SWEC BOP Design Study
- June 4, 1993 SQN Secondary Plant Reliability Study
- 1995 Plant Reliability Team Report

J. Past Failure Recurrence Control Associated With System 6

Vertical Slice Findings:

1. The prioritization and scheduling of maintenance and modification work is not aggressively focused on improving plant reliability.

2. Site skills need to be strengthened to improve reliability.

3. Parts/material availability is not structured to support plant reliability.

4. Communication/interface (information transfer) between departments needs strengthened.

5. Integrated site organization responsibilities necessary to maintain high plant reliability have not been effective.

6. Sequoyah management does not adequately promote proactive thoughts and actions.

7. Technical Support does not take an adequate role in ensuring systems are maintained reliable.

8. Component Engineering does not take an adequate role in ensuring plant components are maintained reliable.

9. Sequoyah does not have a formal aging and obsolete equipment program.

10. Communication of Standards - Management sends mixed messages relative to standards and expectations of individual performance related to reliable system operation.

11. Technical overview of the PM program is inadequate.

12. System Design- The design bases for system 6 are not well documented and the design is more complex as a result of original design focus on cycle efficiency and not reliability or maintenance.

13. The site did not effectively complete recommendations identified during previous BOP reliability studies.

Attached Data:

1. SQN Comparison to Design Standard, DS-M2.5.1
2. Complexity Relationship Between SQN and Other Plants
3. Production Schedule Performance, WRs/WOs Removed From Schedule During Schedule Development Process

Project Plan for Integrated
Sequoyah Capacity Factor Improvement Assessment

1/14/96

Prepared By:

J. Summy

Submitted By:

M. Lorek

D. Lundy

M. Skarzinski

J. Robertson

Reviewed By:

W. Lagergren

Approved By:

R. Adney

Project Plan for Integrated
Sequoyah Capacity Factor Improvement Assessment
1/14/96

Objective

To immediately correct identifiable plant component deficiencies that are determined to exist at Sequoyah Station which may result in continuing challenges to stable plant operation. Additionally, conduct a detailed comprehensive assessment of the Sequoyah Stations components, systems, processes, and organizations. The purpose of this portion of the assessment, in addition to identifying potential hardware issues, is to identify the underlying common causes of the ongoing continuous challenges to stable operation caused by equipment, processes, and organizations. Once these common causes are identified and validated, effective corrective actions will be developed to ensure long term component reliability. This will be accomplished by improving identified process breakdowns and organizational ineffectiveness which will ultimately improve overall plant availability through more stable plant operations.

Background

Although steady improvements continue to be made in numerous areas throughout the Sequoyah Station, superior station performance is constantly being challenged by overall low component reliability. Evaluated individually each event may appear random in nature and isolated in occurrence. However, when viewed collectively by overall plant performance it is obvious that component reliability is not satisfactory compared to industry high performing analogues.

Significant resources have been applied through various previous initiatives focusing on reliability issues and single failure type items. These initiatives have been successful, however, plant performance continues to suffer due to component unreliable operation particularly related to balance of plant systems. Senior station management has recognized that a different approach is needed to assist in resolving this long standing problem. The approach agreed upon as described below is that multiple parallel paths will be pursued concurrently to ensure a complete root cause analysis of the cause(s) of unreliable components.

Approach

The below described approach to performing this integrated investigation is based on the following assumptions:

- component maintenance in the form of adequacy of past and current preventive maintenance activities or component trending have been or continue to be insufficient to prevent detection and correction of component failures,

- component maintenance in the form of corrective maintenance adequacy have been less than fully effective to prevent recurring component failures,

- maintenance work practices, craft skills, and organization to organization deficiencies may be contributing to the less than effective component maintenance since these are common to both preventive and corrective maintenance,

- incorrect operation with respect to how the original design had intended them to be operated may be contributing to premature component failures,

- lack of effective root cause analysis for failures may as a minimum fail to predict, therefore, prevent new failures and inappropriate corrective actions may actually contribute to increasing the failure population prematurely,

- lack of a rigorous, integrated (operational, maintenance, design) review on a systematic requirements basis has never been performed. Therefore, the potential exists that incorrect component integration is resulting in premature failures,

- ineffective prioritization of management attention to emerging maintenance items that do not immediately impact plant production potentially has resulted in low sensitivity, therefore, less than adequate concerns over certain plant components,

- lack of an effective station work prioritization process has resulted in resource allocations that have not obtained measurable capacity factor improvements,

- lack of effective monitoring for adverse trends with respect to repetitive maintenance problems and or non safety system component performance may be allowing less than acceptable overall plant performance to exist over time.

Since these assumptions involve; equipment failure issues, individual worker skills, possible programmatic deficiencies, and integration irregularities the investigation must be completed in a fashion to address all of these potential "drivers" to component unreliability. Once all of these areas are investigated then the common causes behind the majority of the contributing factors may be determined and corrected. This approach to the investigation will ensure that as individual items are determined, those resulting in less than desirable component reliability, will individually be corrected. Additionally, the common causes (potentially the work practices, programmatic issues, or organizational inefficiencies) which have been allowed to exist and have resulted in low component reliability will also be resolved. The investigation therefore, will be divided into four main approaches as described below. These are all intended to be performed in parallel during a three week period.

Investigation Team 1

This team lead by Mike Lorek will conduct a series of group discussion sessions with personnel in each of the following major disciplines: Operations, Maintenance, Technical Support, Component Engineering, and Nuclear Engineering. Each of these group discussion sessions will be structured and facilitated in a similar fashion to perform the following. Attempt to surface any known potential repetitive plant problems that are currently thought to exist or which might exist in the future. Attempt to determine the underlying reason why our normal processes, programs, or organizational structures have prevented these from being identified and fixed previously. Use actual case studies pertinent to the subject group which have occurred recently in the plant and ask the group to identify why they believe this problem or type of problem could have occurred. Attempt to identify how managers track plant concerns or repetitive failures such as those being discussed and how they know if items are being tracked or not.

Mike Lorek and Tom Nahay will be the facilitators for each of these group discussion sessions along with one or more credible members of the staff participating in the session. The objective of these sessions is three fold. First is to identify possible organizational and programmatic causes that are inhibiting our abilities to self identify and correct problems. Second is to help identify potential new failure items which might exist in the plant. Thirdly is that common themes across all the sessions will be evaluated to assist in long term corrective measures to increase overall component reliability and successful system operation.

Investigation Team 1 will produce the following results upon completion of this portion of the assessment:

1) Construct a list of common concern areas identified by each group with relationship to work processes / programs and organizational deficiencies which the group feels may be resulting in problems not being resolved.

2) A list of potential hardware deficiencies identified by the individuals participating in the group discussions. Each item, if possible, should be tracked by who, or at least what group, identified the potential problem so that if additional information is required to further identify the concern additional information may be obtained from the originator. This list will subsequently be evaluated for inclusion into a master items list for correction of deficiencies.

3) Upon completion of the group discussion sessions construct a matrix of identified programmatic and organizational concerns by group along with a listing of hardware problems which were identified.

Project Plan for Integrated
Sequoyah Capacity Factor Improvement Assessment
1/14/96

Investigation Team 2

Dennis Lundy as Investigation Team Leader will conduct a detailed review of existing data sources relating to component performance in each of the following areas: Operations, Maintenance, Engineering / Materials. Data sources such as Business Plan, 39 Capacity Loss Events (93-95), Plant trip near misses, Configuration PER's, Selected PER's in the area of evaluation, work prioritization, procedure / clearance errors, system problems (ops, maint, eng/material) blue card observations, external agency reviews/reports, system health reports, repetitive problems, previous reliability study results, work around lists, temporary modifications, NPRDS, open PER currently under evaluation by Paul Trudel of Tech Support concerning refueling outage identified component failures, review of maintenance items being deferred from U2C7 refueling outage work list, review of future design changes for partial implementation, etc.

Each area would use an integrated team approach (Sequoyah, Corporate, Browns Ferry) personnel to assist Dennis in review of the data and determination of the issues which are important to that area. Dennis will make final recommendations to the overall investigation lead. Both individual hardware items to be corrected along with common generic concerns would be compared to the findings and recommendations of the other teams.

Investigation Team 2 will produce the following results upon completion of this portion of the assessment:

1) Construct a list of common concern areas identified by each group with relationship to work processes / programs and organizational deficiencies which the group feels may be resulting in problems not being resolved.

2) A list of potential hardware deficiencies indicated as potential items to be corrected to increase component reliability. Each item will be tracked by the group and data source which originally identified the potential problem so that if additional information is required to further identify the concern that information may be obtained from the originator. This list will subsequently be evaluated for inclusion into a master items list for correction of deficiencies.

3) Upon completion of the data review sessions construct a matrix of identified programmatic and organizational concerns by group along with a listing of hardware problems which were identified.

Project Plan for Integrated
Sequoyah Capacity Factor Improvement Assessment
1/14/96

Investigation Team(s) 3

Team leader Mark Skarzinski will perform an integrated systematic review of the heater vents and drains system with respect to all aspects of that systems performance: operational, maintenance, and design. This system was chosen from the complete list of balance of plant systems for numerous reasons. The review will identify not only the specific concerns that might be impeding reliable operation of this system but the larger organizational and programmatic issues that might be generic to all systems. The individual hardware and procedural problems along with any generic programmatic and organizational concerns will be used to compare to the common findings of the other Investigation Team findings. Special organizational or training needs associated with operations of a complex balance of plant system will be evaluated.

The method for conducting this detailed systematic review will be based on an approach used at other sites such as Oyster Creek which have conducted similar reviews of systems. Based on the overall findings resulting from this single system evaluation and the overall investigation determinations, additional systems may be suggested to undergo this similar review.

Mark will utilize an integrated review team consisting of Operations, Tech Support, Component Engineering, Nuclear Engineering, Maintenance (PM, Planning, Craftsman), and Materials to ensure a thorough evaluation is made of all aspects of system reliability.

Investigation Team 3 will produce the following results upon completion of this portion of the assessment:

1) Construct a list of common concern areas identified by the review with relationship to work processes / programs and organizational deficiencies which the group feels may be resulting in problems not being resolved on the system.

2) A list of potential hardware deficiencies identified by the evaluation team. Each item will be tracked by the reason for identification and the potential problem which will result, if not corrected, so that if additional evaluation is required to further help prioritize the concern this data will be readily available. This list will subsequently be evaluated for inclusion into a master items list for correction of deficiencies.

3) Upon completion of the detailed review construct a matrix of identified programmatic and organizational concerns by area of concern along with a listing of hardware problems which were identified.

Investigation Team 4

Jerry Robertson, will perform a common cause analysis on the more significant events which occurred in 1995 and produce a resulting conclusion of the root causes of these events. This would involve a detailed review of significant events from 1995 such as LER's, NOV's, PER's with root cause analysis to determine the underlying causes for these events. This will assist in determining the underlying reasons for recent events and how these causes compare to the findings of the other aspects of the investigation.

Investigation Team 4 will produce the following results upon completion of this portion of the assessment:

1) A detailed analysis of the various causes of the analyzed problems in various areas such as: causing organization, work process / program, organizational and programmatic failure mode, and what was done to prevent recurrence of the event.

2) Construct a list of the significant common concern areas identified along with an overall conclusion regarding the analysis.

3) Identify recommended corrective actions to prevent recurrence of the common causes to the observed inappropriate actions.

4) Present the findings and conclusion of the common cause analysis to the overall investigation group and assist in evaluation of common causes identified by teams 1 through 3 to determine overall corrective actions.

Overall Investigation Team

Bill Lagergren, the overall investigation leader, along with the team leaders Mike Lorek, Mark Skarzinski, Dennis Lundy, and Jerry Robertson from each of the individual investigation teams will form the final overall investigation team. This group of individuals will coordinate and review all individual team findings along with the common findings. The overall investigation team will appraise senior station management of the progress and status of the investigation along with developing corrective actions to increase component reliability. This aspect of the investigation is anticipated to take two weeks.

Overall Investigation Team will produce the following results upon completion of this portion of the assessment:

1) Weekly status briefings to the MRC on Friday of each week. These status briefings will provide the MRC with any preliminary findings which require immediate attention to resolve, status with respect to schedule, identification of any difficulties being encountered or needs for additional support, and other issues as determined by the overall investigation team leader or the MRC Chairman.

2) Provide a final report with recommendations in the following main areas as a minimum:

    a) organizational and programmatic corrective actions to prevent these types of deficiencies from recurring in the future,

    b) components requiring additional attention to ensure increased overall plant stability and,

    c) special insights related to the operation and maintenance of complex balance of plant systems.

3) Recommendations of any follow on efforts required such as additional systems which may require full systematic assessment as performed by Investigation Team 3.

4) Assessment as to the overall effectiveness of the assessment and need to perform any additional assessments not already performed.

ATTACHMENT 4

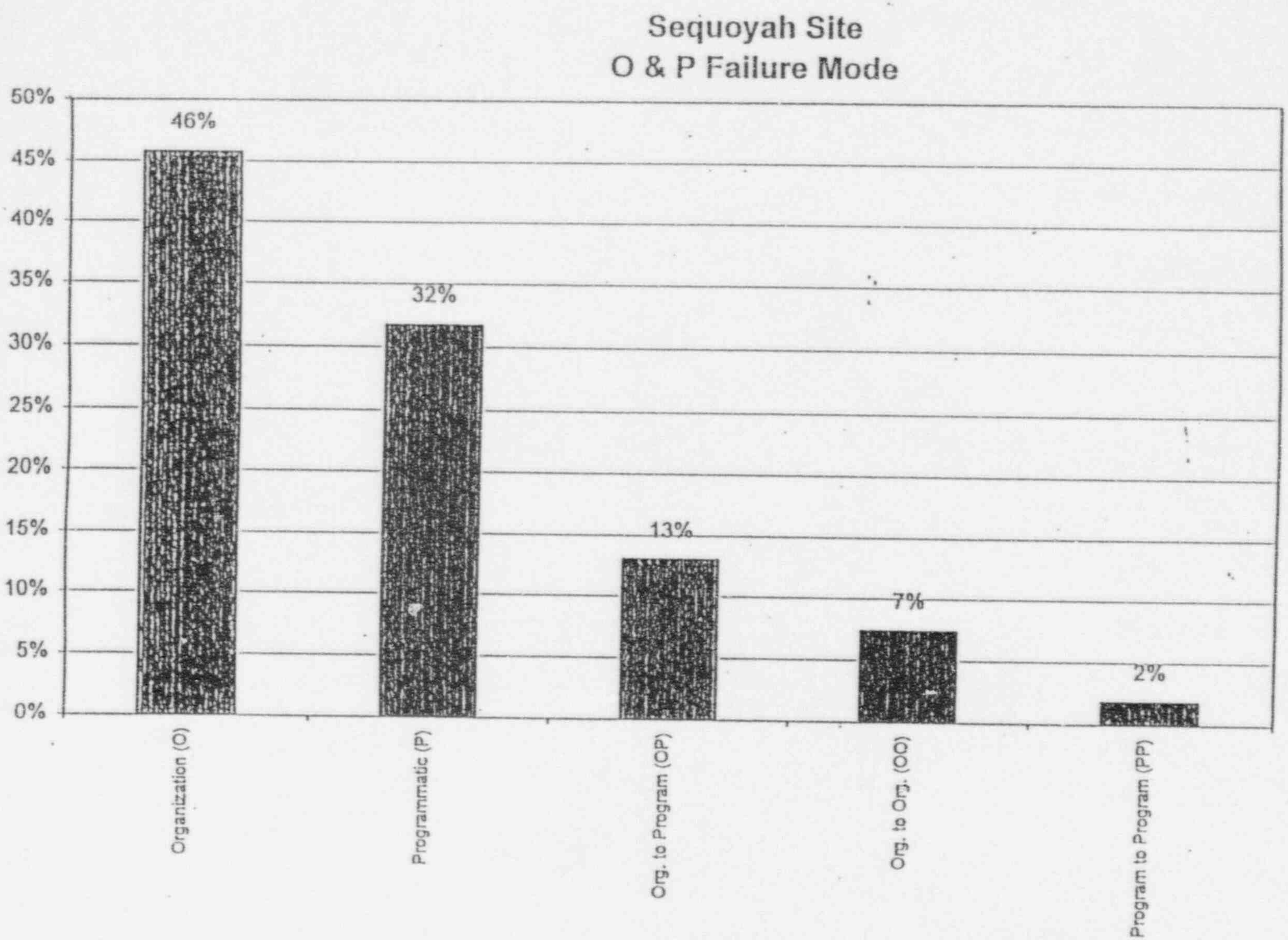

Sequoyah Site
O & P Failure Mode
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
46%
32%
13%
7%
2%
Organization (O)
Programmatic (P)
Org. to Program (OP)
Org. to Org. (OO)
Program to Program (PP)

Figure 2

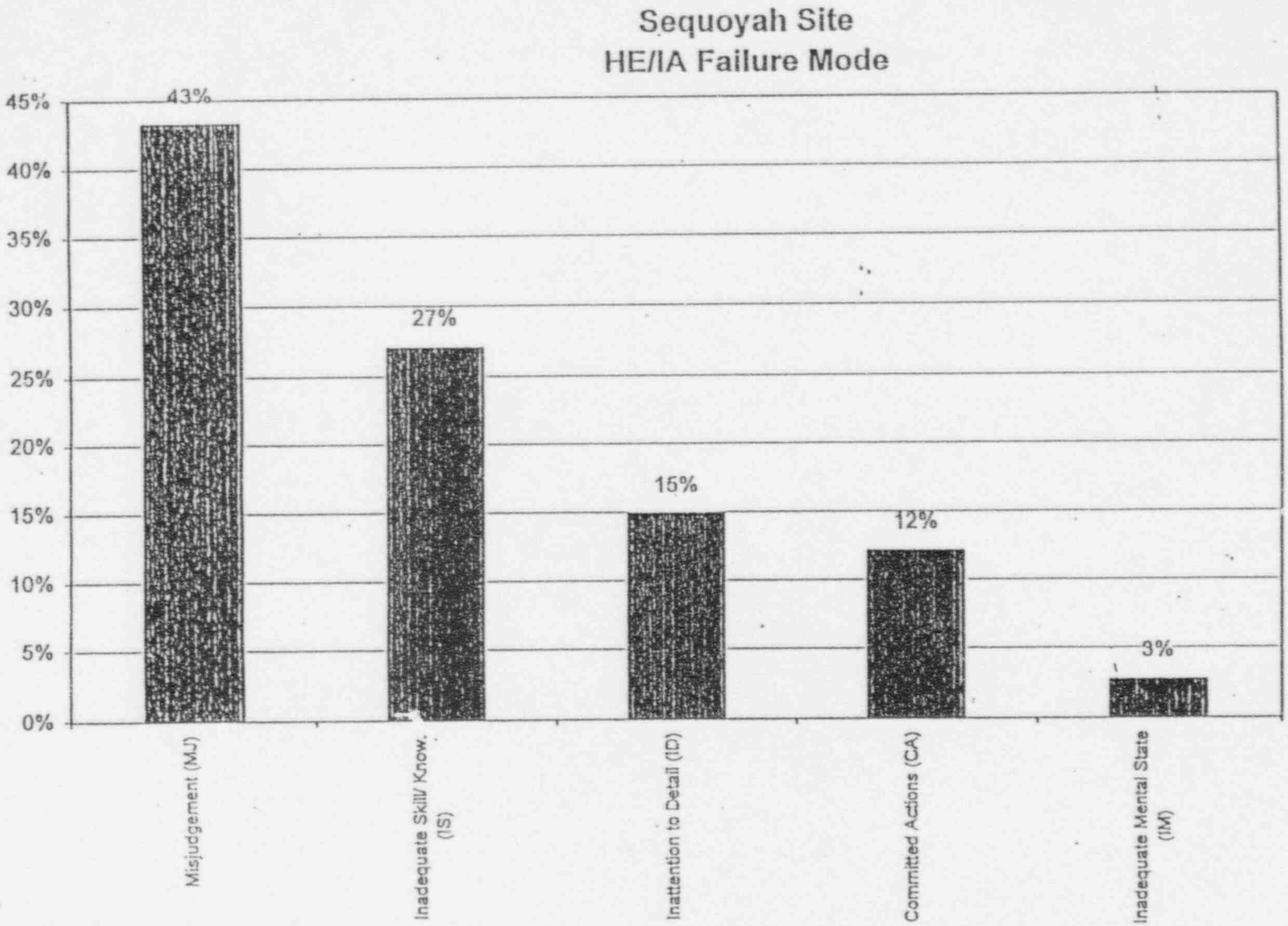

Sequoyah Site
HE/IA Failure Mode
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
43%
27%
15%
12%
3%
Misjudgement (MJ)
Inadequate Skill/ Know. (IS)
Inattention to Detail (ID)
Committed Actions (CA)
Inadequate Mental State (IM)

Figure 3

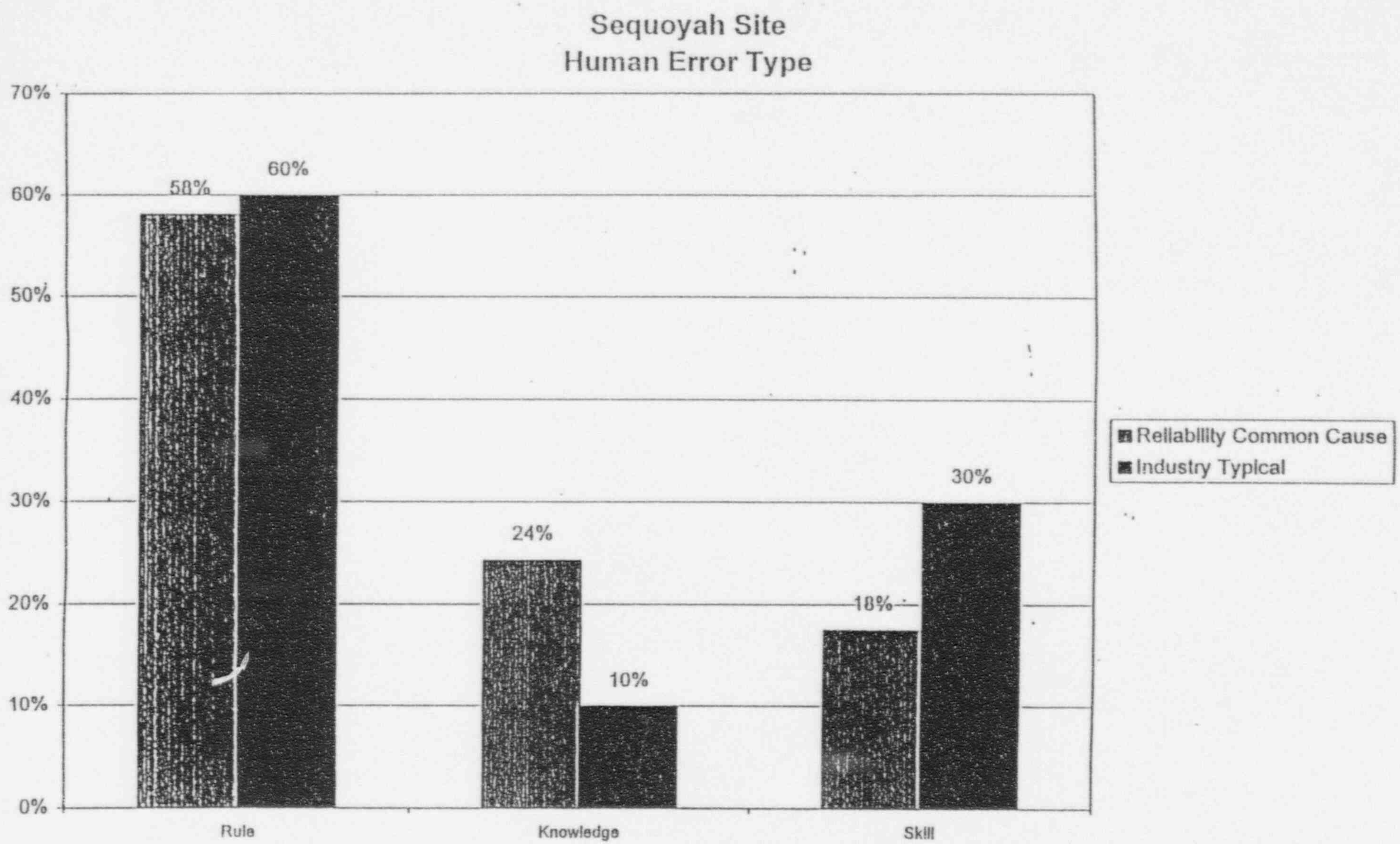

Sequoyah Site
Human Error Type
70%
60%
50%
40%
30%
20%
10%
0%
58%
60%
24%
10%
18%
30%
Rule
Knowledge
Skill
Reliability Common Cause
Industry Typical

Figure 4

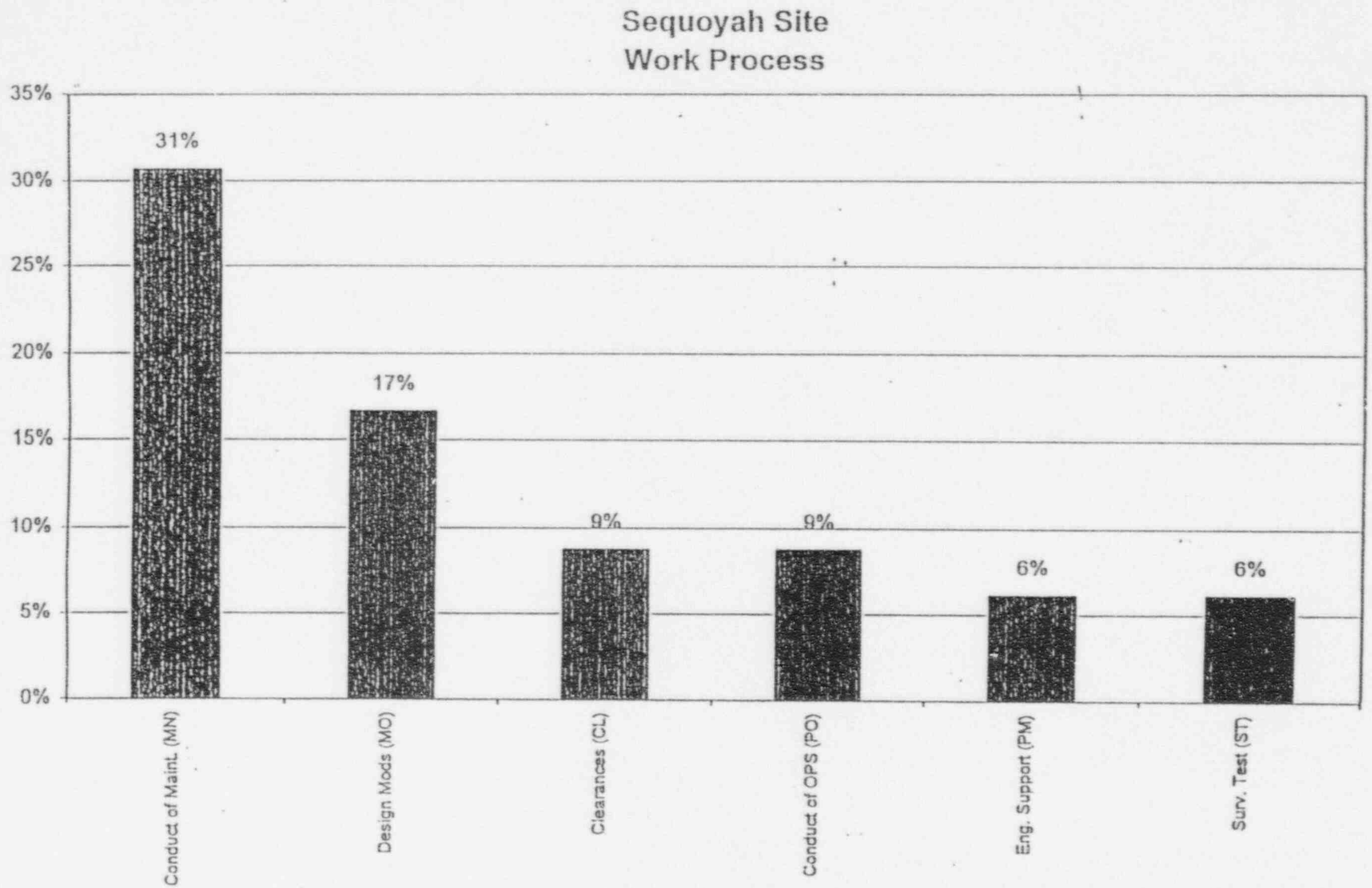

Sequoyah Site
Work Process
35%
30%
25%
20%
15%
10%
5%
0%
31%
17%
9%
9%
6%
6%
Conduct of Maint. (MN)
Design Mods (MO)
Clearances (CL)
Conduct of OPS (PO)
Eng. Support (PM)
Surv. Test (ST)

Figure 5

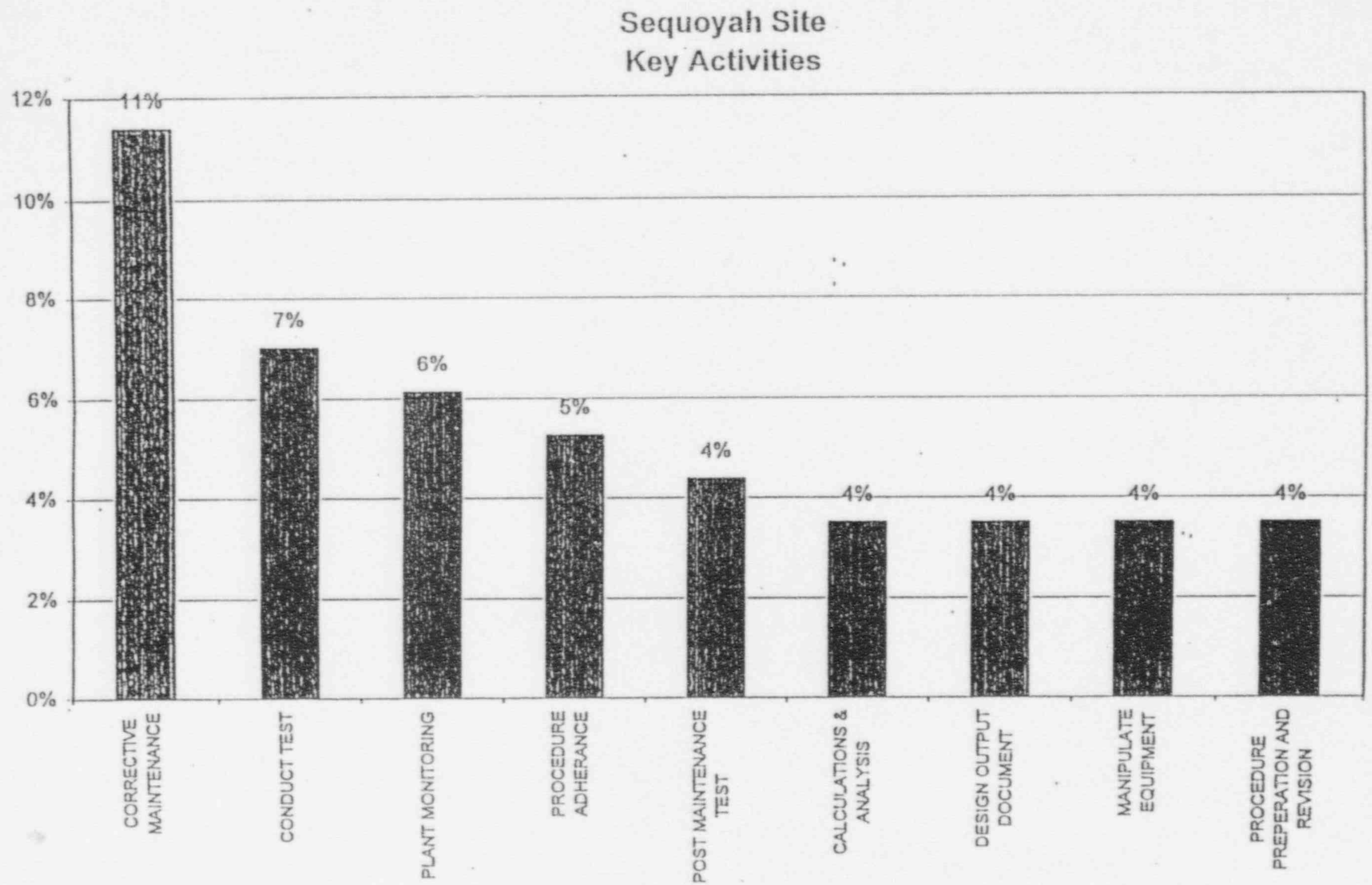

Sequoyah Site
Key Activities
12%
10%
8%
6%
4%
2%
0%
11%
7%
6%
5%
4%
4%
4%
4%
4%
CORRECTIVE MAINTENANCE
CONDUCT TEST
PLANT MONITORING
PROCEDURE ADHERANCE
POST MAINTENANCE TEST
CALCULATIONS & ANALYSIS
DESIGN OUTPUT DOCUMENT
MANIPULATE EQUIPMENT
PROCEDURE PREPERATION AND REVISION

Figure 6

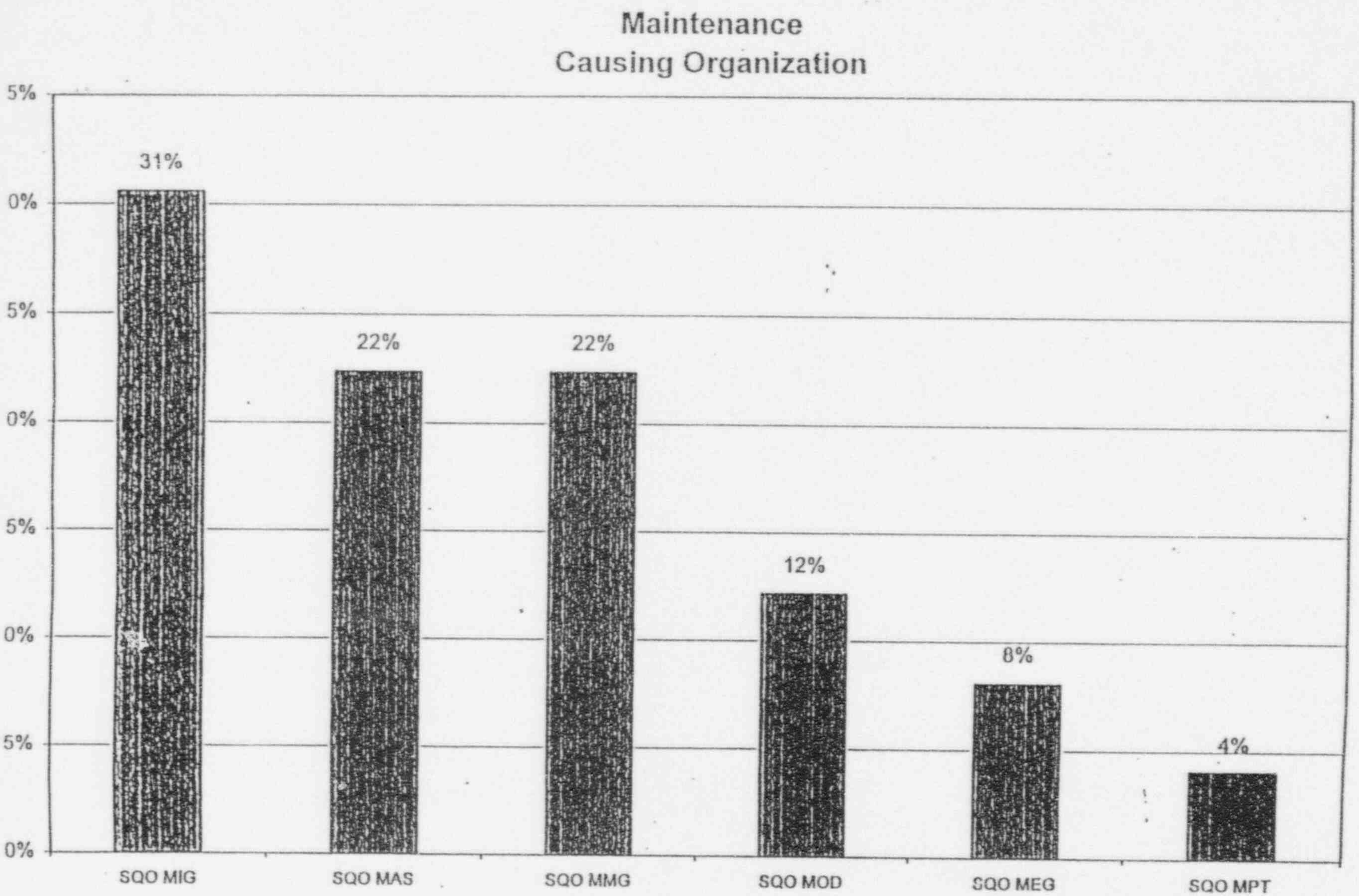
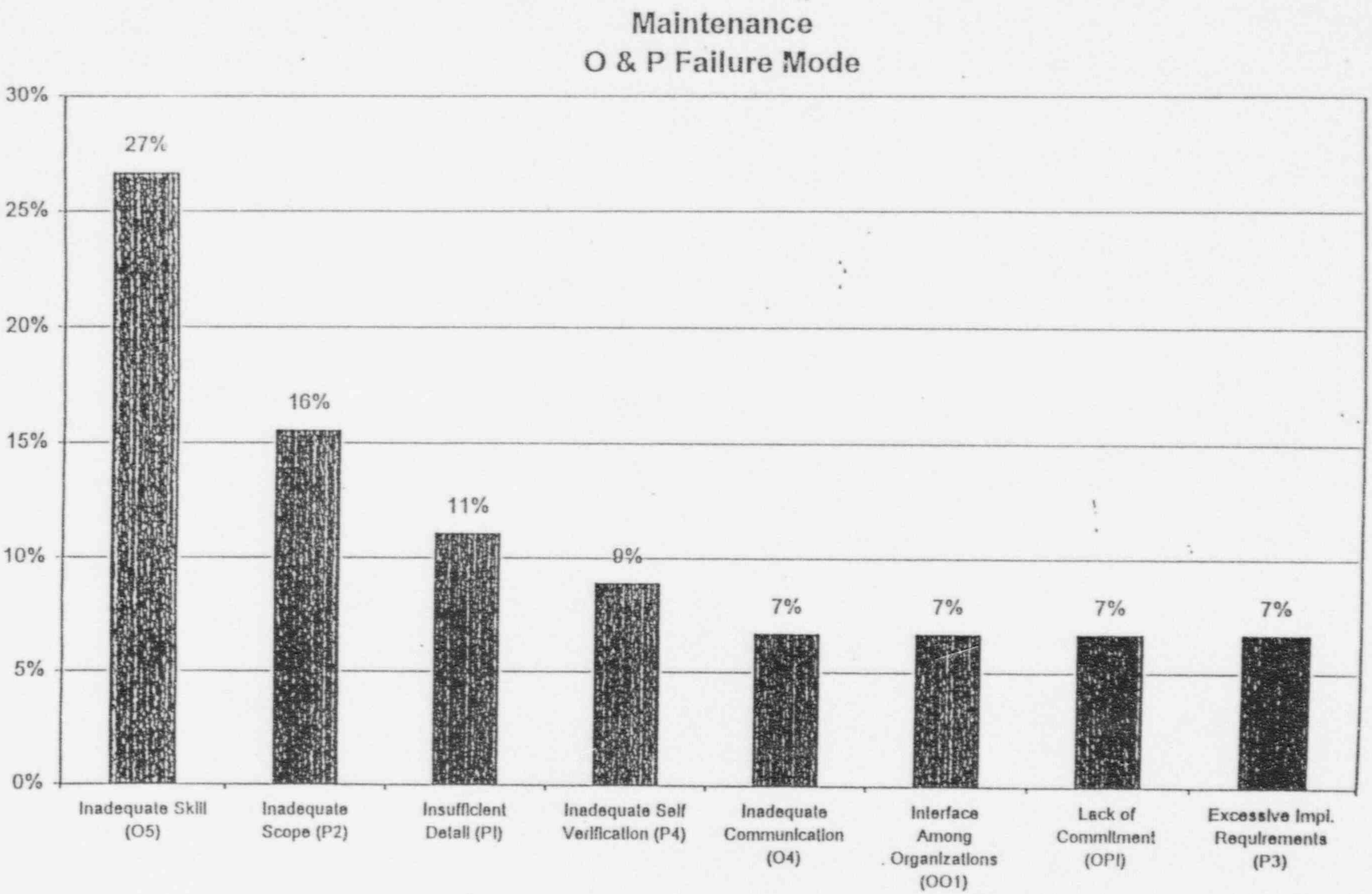

Maintenance
Causing Organization
5%
0%
5%
0%
5%
0%
5%
0%
31%
22%
22%
12%
8%
4%
SQO MIG
SQO MAS
SQO MMG
SQO MOD
SQO MEG
SQO MPT

Figure 8



Maintenance
O & P Failure Mode
30%
25%
20%
15%
10%
5%
0%
27%
16%
11%
9%
7%
7%
7%
7%
Inadequate Skill (O5)
Inadequate Scope (P2)
Insufficient Detail (PI)
Inadequate Self Verification (P4)
Inadequate Communication (O4)
Interface Among Organizations (OO1)
Lack of Commitment (OPI)
Excessive Impl. Requirements (P3)

Figure 9

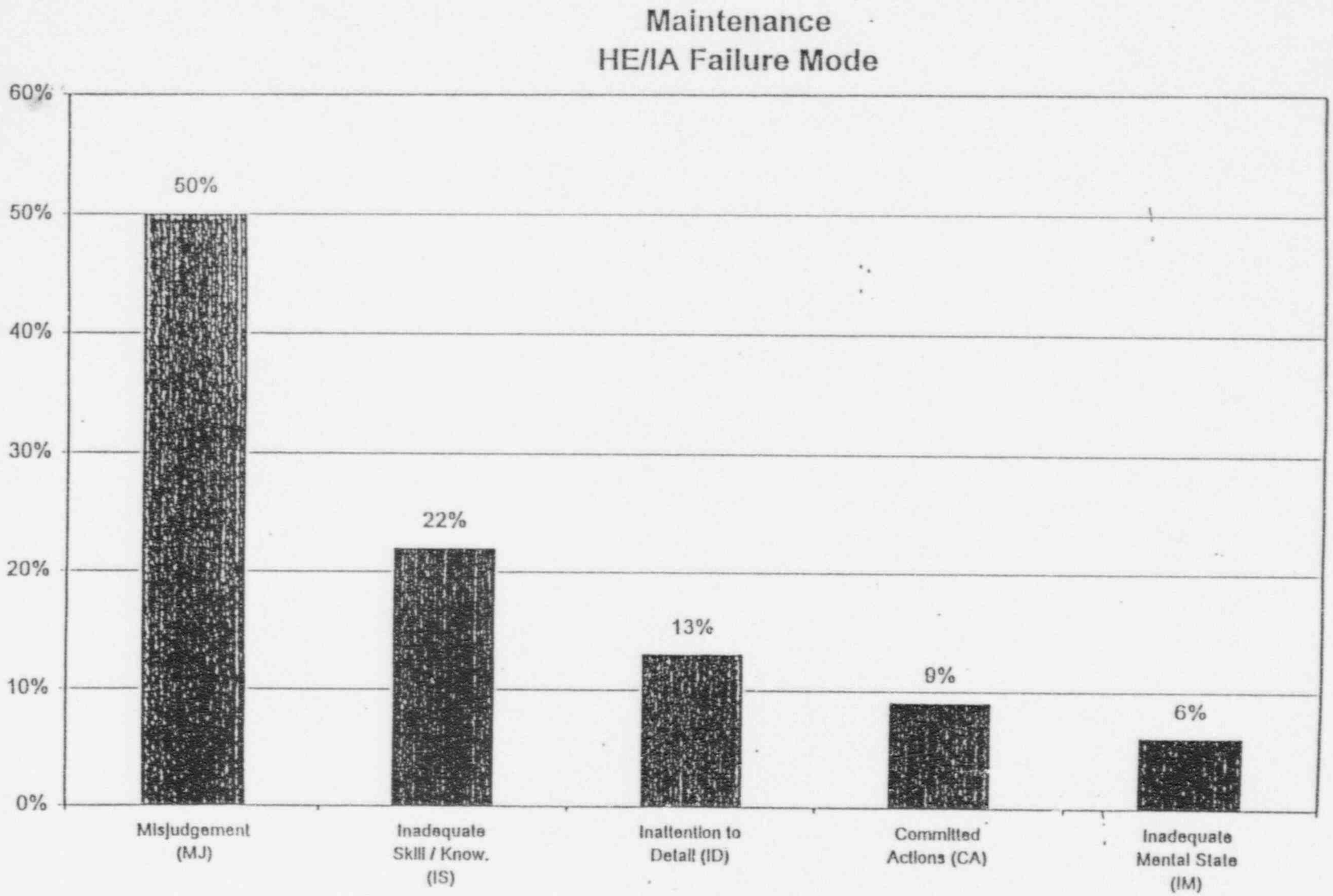
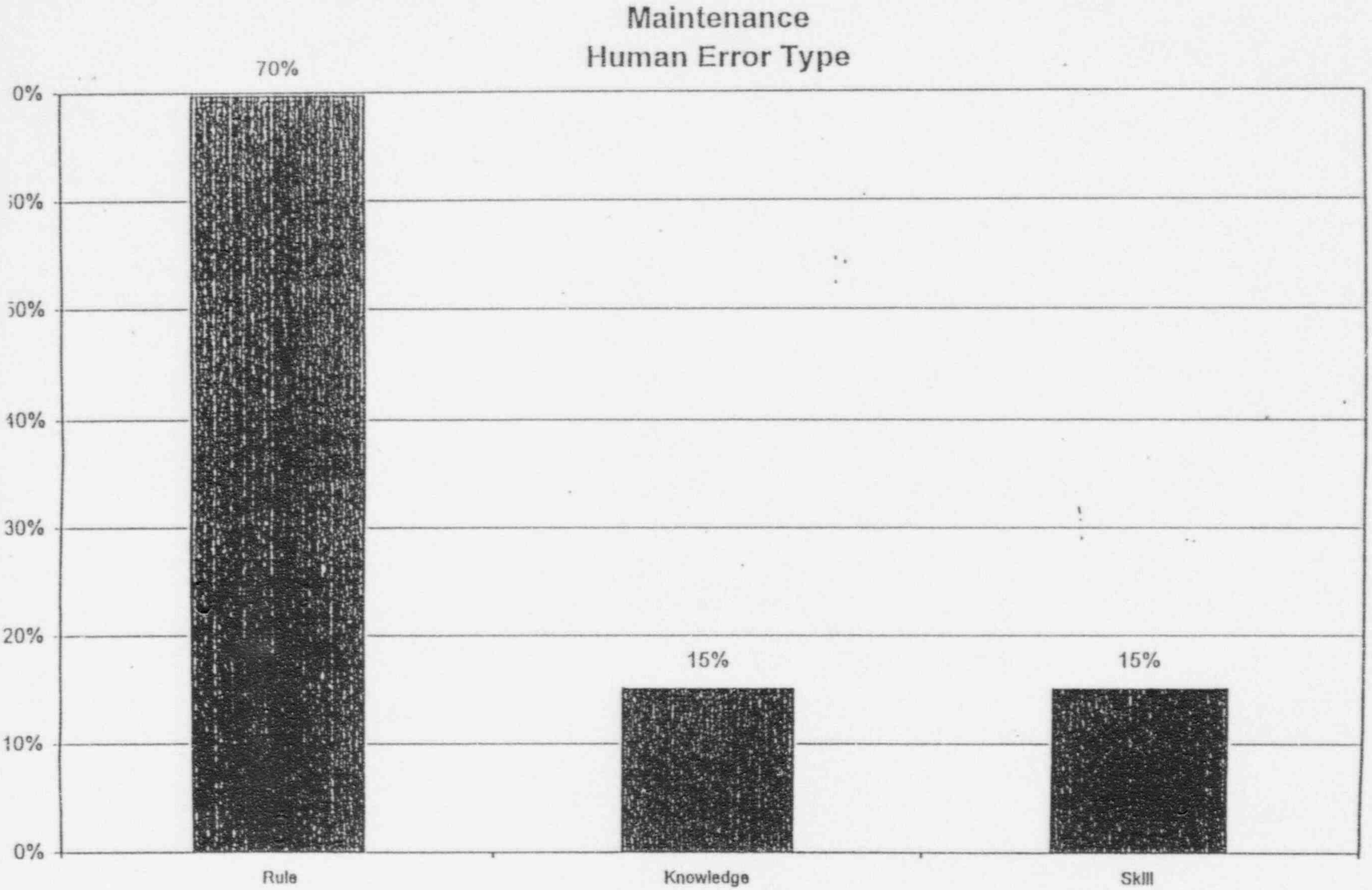

Maintenance
HE/IA Failure Mode
60%
50%
40%
30%
20%
10%
0%
50%
22%
13%
9%
6%
Misjudgement (MJ)
Inadequate Skill / Know. (IS)
Inattention to Detail (ID)
Committed Actions (CA)
Inadequate Mental State (IM)

Figure 10



Maintenance
Human Error Type
70%
0%
;0%
;0%
10%
30%
20%
10%
0%
15%
15%
Rule
Knowledge
Skill

Figure 11

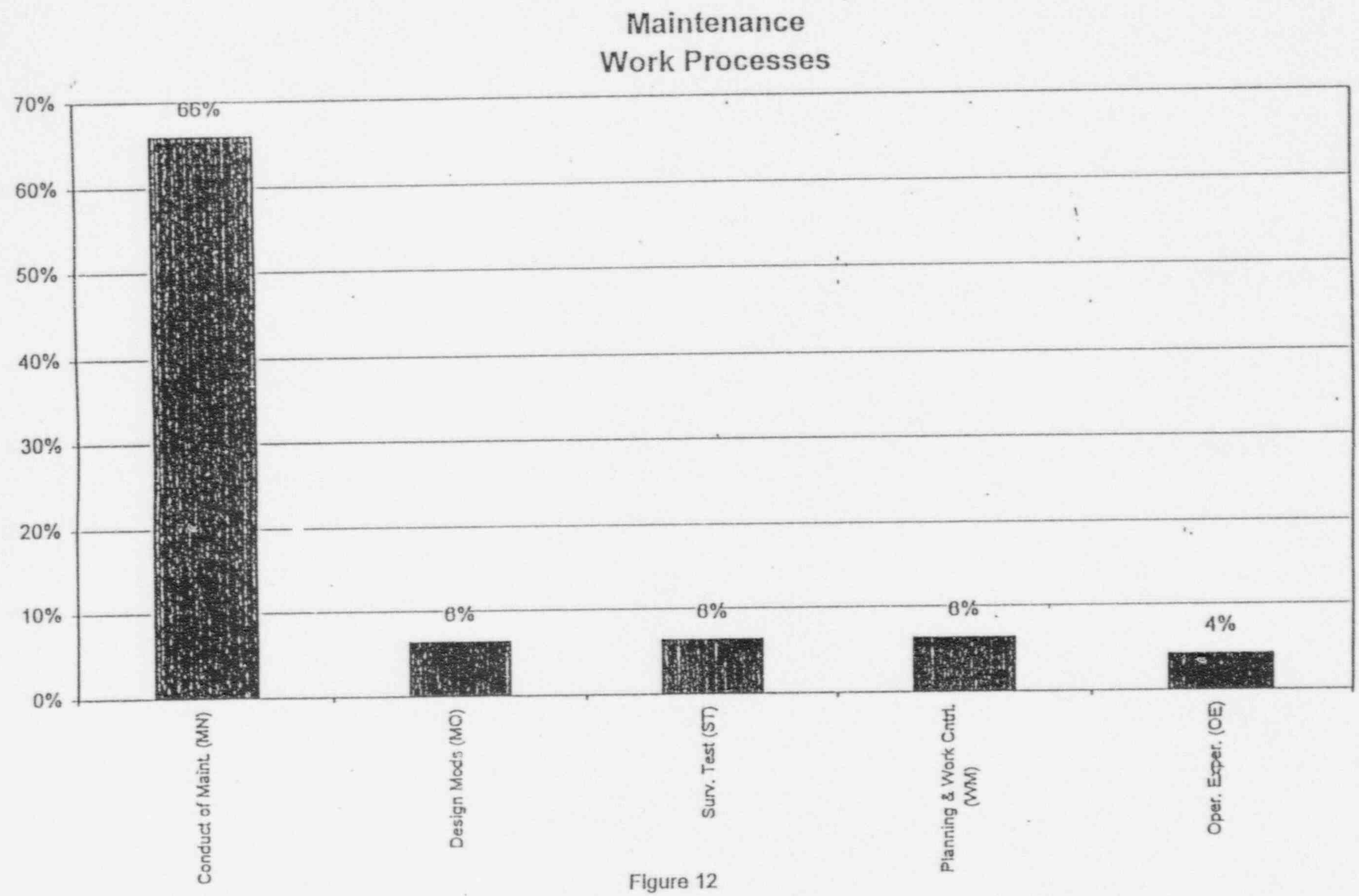

Maintenance
Work Processes
70%
60%
50%
40%
30%
20%
10%
0%
66%
6%
6%
6%
4%
Conduct of Maint. (MN)
Design Mods (MO)
Surv. Test (ST)
Planning & Work Cntrl. (WM)
Oper. Exper. (OE)

Figure 12

Maintenance
Key Activities

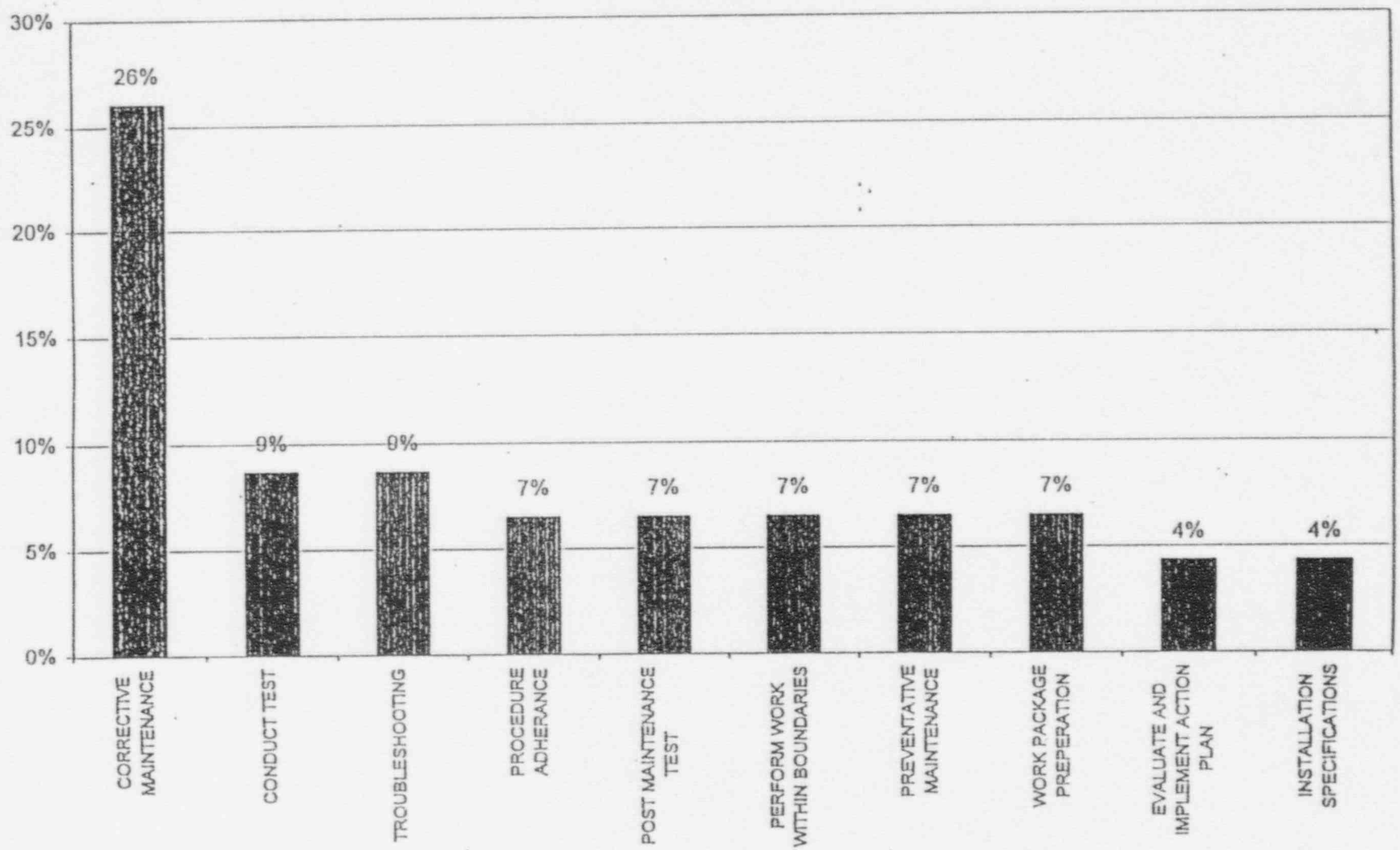
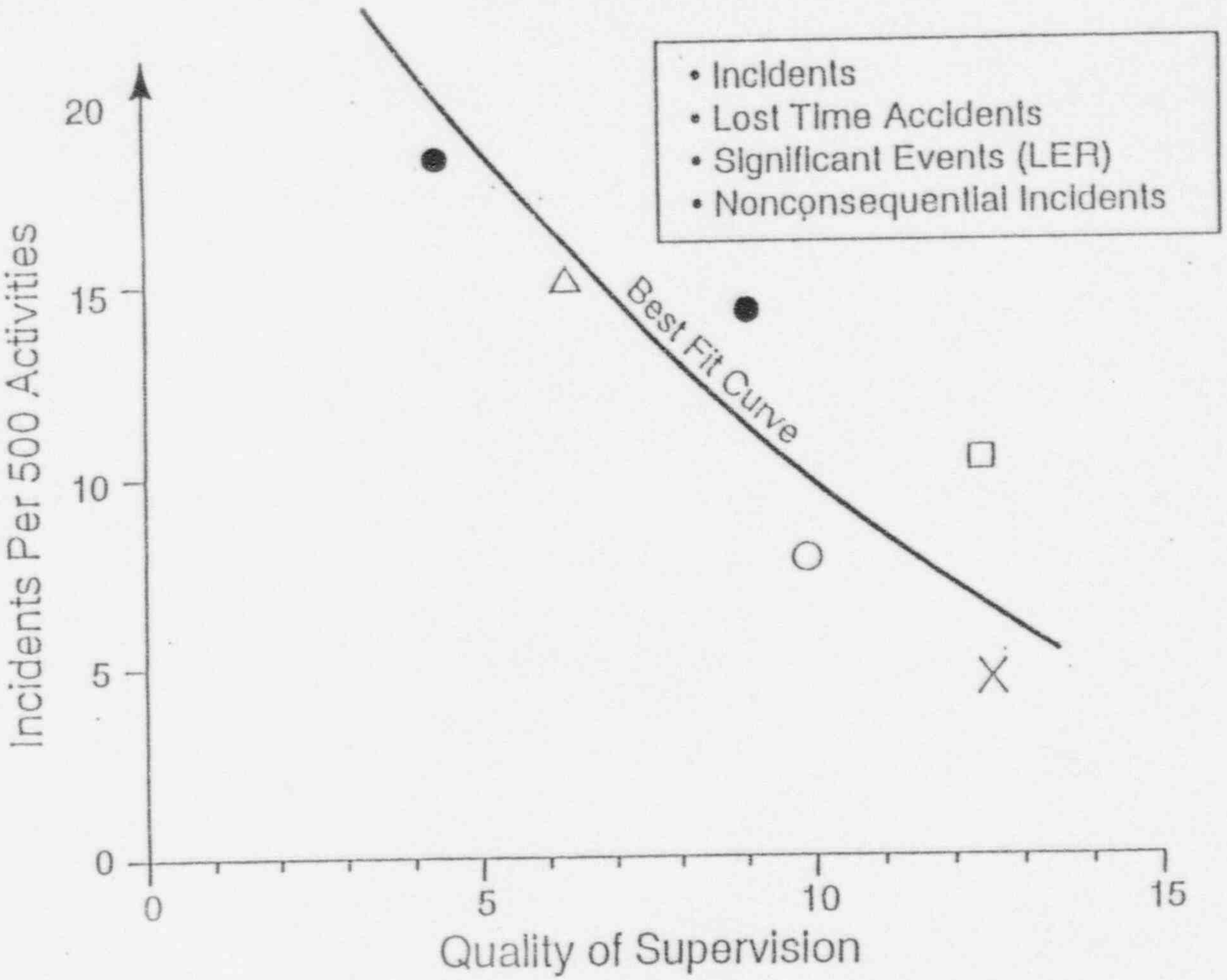


Figure 13

Human Error Rate Versus Quality of Supervision

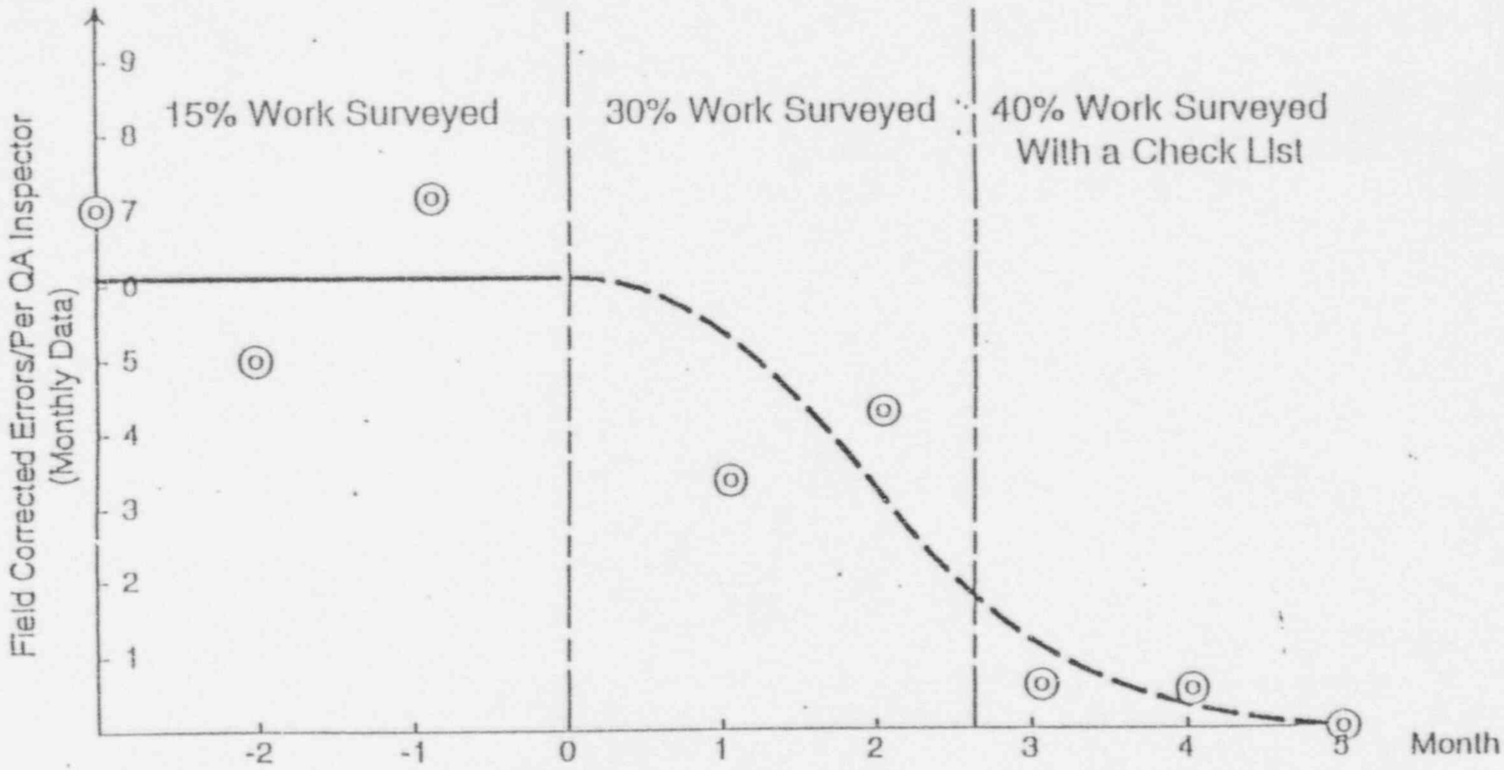


**Data taken from six maintenance groups over a period of one to two months*

FIGURE 14

Positive Effect of Field Surveillance

*(Maintenance Work)**



**Data taken at a West Coast plant from July 1993 to 1994*

FIGURE 15

Quality of Supervision for Error Reduction

Good Supervisors	Bad Supervisors
• Minimize unwanted scheduler pressure	• Expect staff to work under tight schedule all the time
• Check on work during progress	• Only check the paper work
• Assign right workers for the right job	• Assign inexperienced people to tough jobs
• Check if all needed information is provided	• Shy away from questions during work
• Detect conditions that are conducive to human errors before work	• Ignore all the traps and treat the tailboard meeting as a nuisance

FIGURE 16

HUMAN ERROR CHECKLIST --

SUPERVISORY FIELD SURVEILLANCE

		Yes	No
1.	Do workers have the right procedures or aids to carry out their jobs?	____	____
2.	Are all the tools or equipment properly staged?	____	____
3.	Does each worker know his responsibility and work scope?	____	____
4.	Is the work place very distractive?	____	____
5.	Do workers feel high time pressure to complete work?	____	____
6.	Do workers feel required procedures are not necessary?	____	____
7.	Do workers know what the unexpected or abnormal conditions are?	____	____
8.	Do workers know where to find help if abnormal or unexpected conditions arise?	____	____
9.	Do workers act professionally (meet our professional standards) ?	____	____
10.	Do workers know our expectations in procedural compliance, clean-as-we-go, not-proceeding-in-the-face-of-uncertainty, and QV&V all input data?	____	____

FIGURE 17

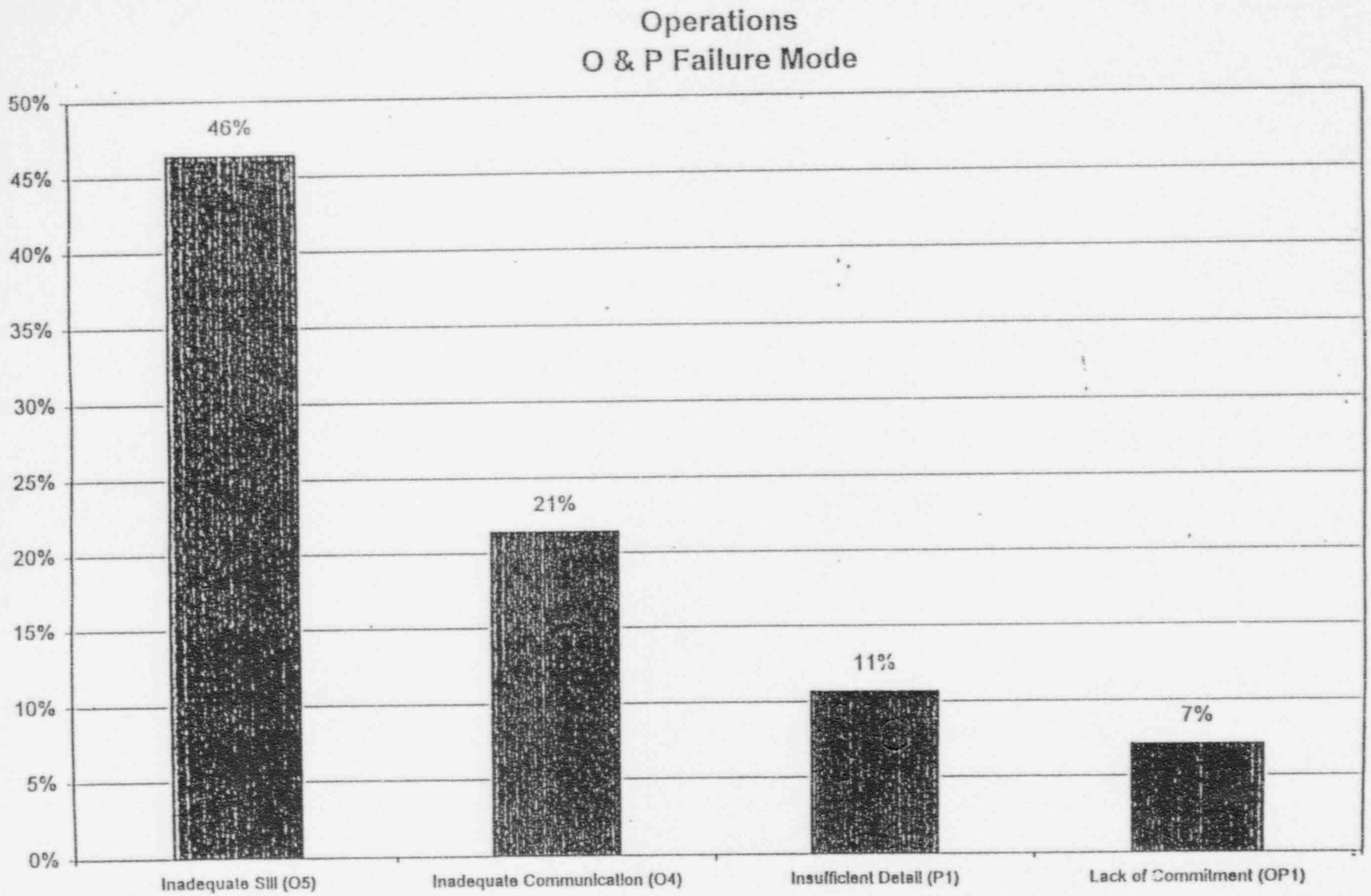

Operations
O & P Failure Mode
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
46%
21%
11%
7%
Inadequate Sill (O5)
Inadequate Communication (O4)
Insufficient Detail (P1)
Lack of Commitment (OP1)

Figure 18

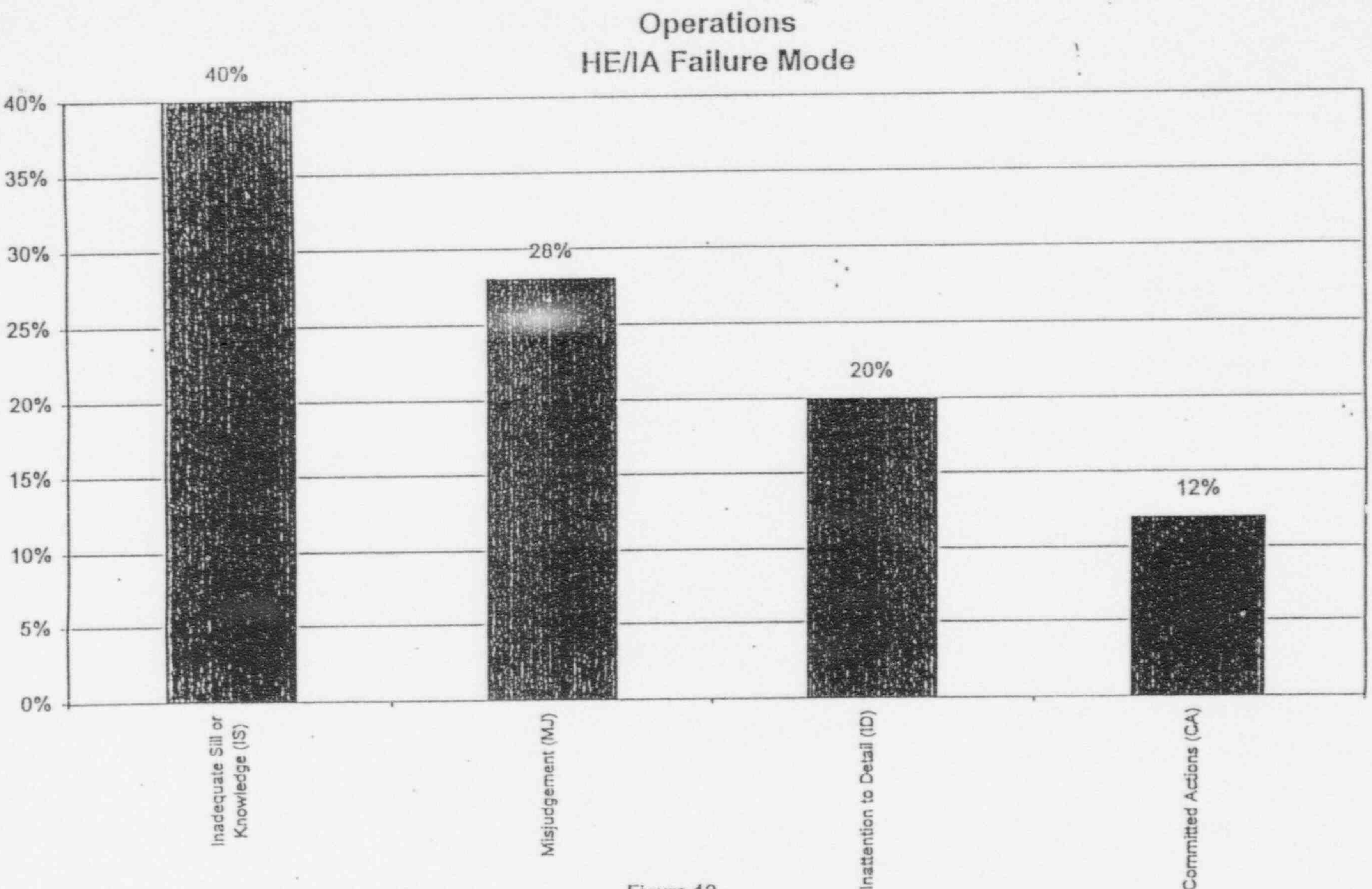

Operations
HE/IA Failure Mode
40%
28%
20%
12%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Inadequate Sill or Knowledge (IS)
Misjudgement (MJ)
Inattention to Detail (ID)
Committed Actions (CA)

Figure 19

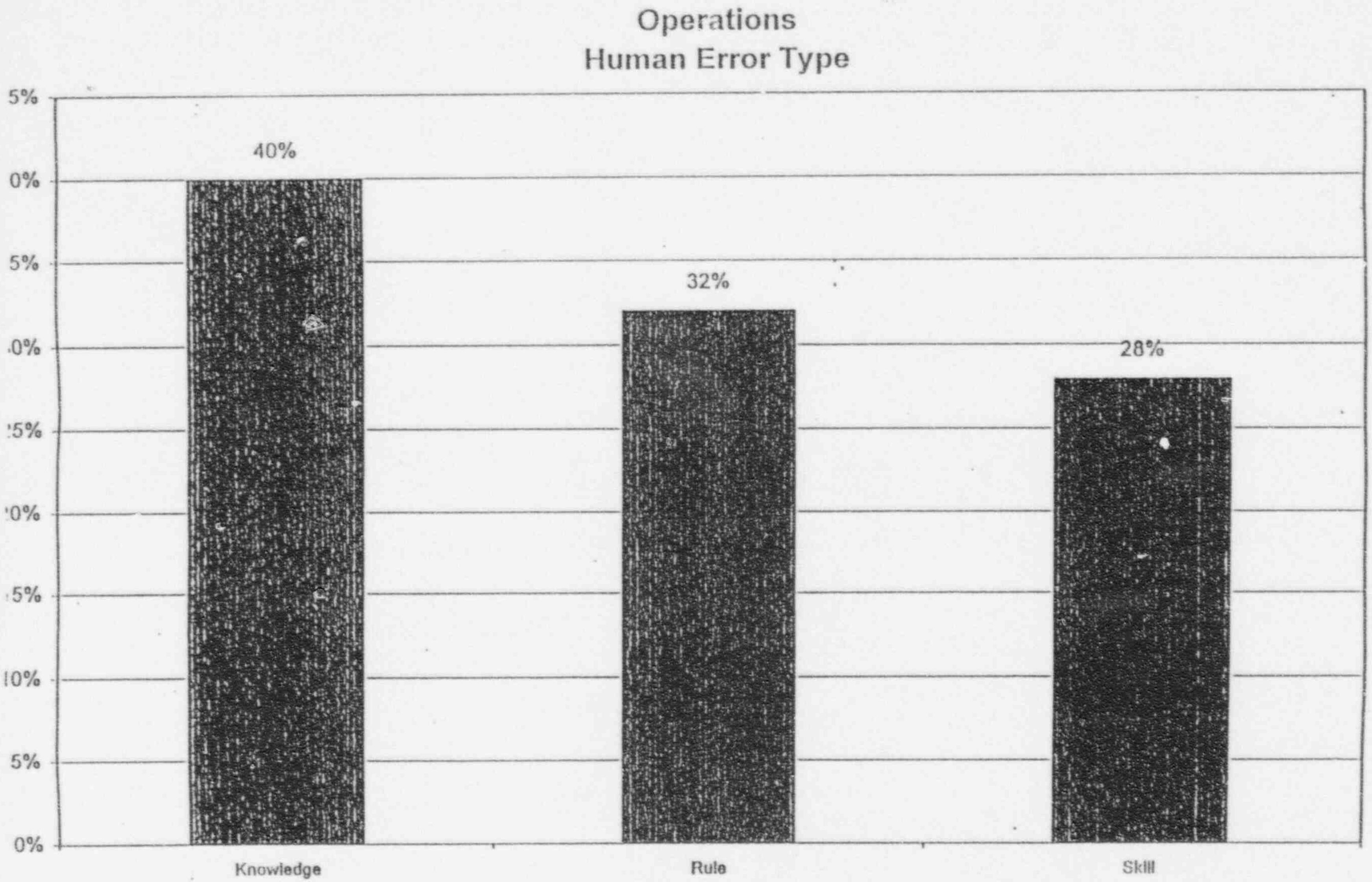

Operations
Human Error Type
5%
0%
5%
0%
5%
0%
5%
10%
5%
0%
40%
32%
28%
Knowledge
Rule
Skill

Figure 20

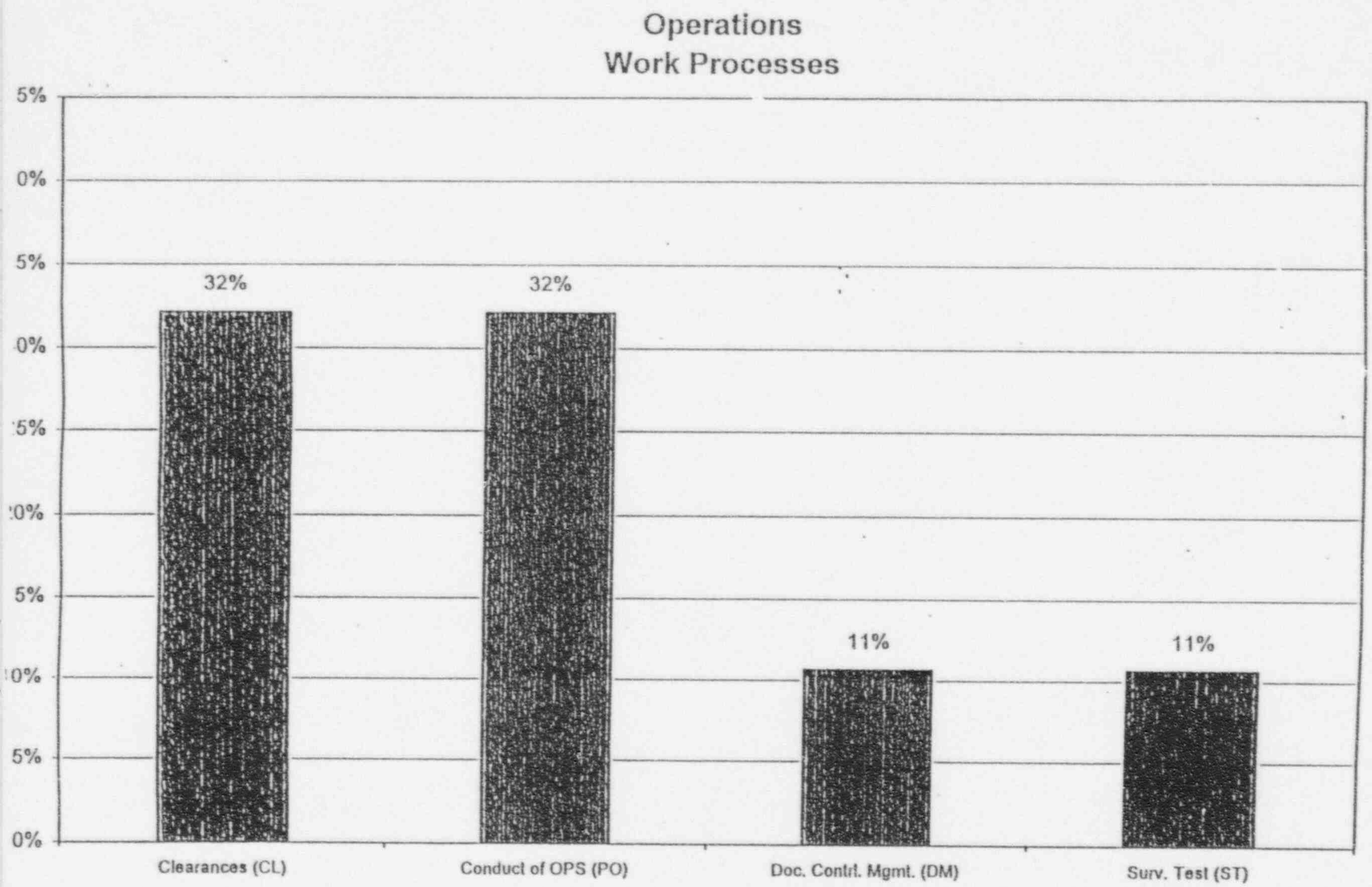
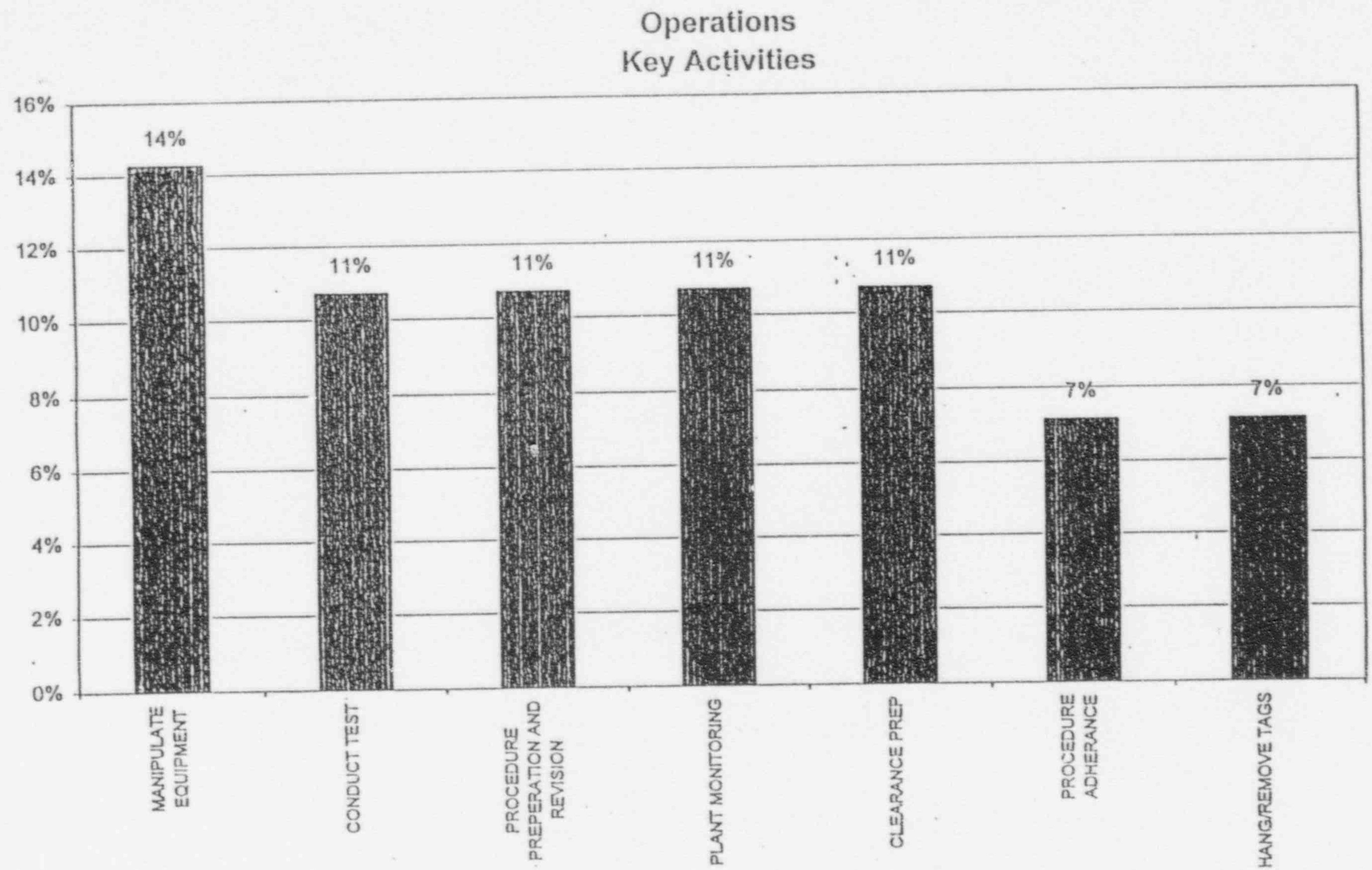

Operations
Work Processes
5%
0%
5%
0%
5%
0%
5%
0%
5%
0%
32%
32%
11%
11%
Clearances (CL)
Conduct of OPS (PO)
Doc. Contrl. Mgmt. (DM)
Surv. Test (ST)

Figure 21



Operations
Key Activities
16%
14%
12%
10%
8%
6%
4%
2%
0%
14%
11%
11%
11%
11%
7%
7%
MANIPULATE EQUIPMENT
CONDUCT TEST
PROCEDURE PREPERATION AND REVISION
PLANT MONITORING
CLEARANCE PREP
PROCEDURE ADHERANCE
HANG/REMOVE TAGS

Figure 22