THE SAFETY INDICATORS PROGRAM IN TAIWAN, CHINA: A SIX-YEAR TREND

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ABSTRACT

This paper presents data on the current operating status and the safety indicators (SI) of the six nuclear power units in Taiwan . Analysis of the data collected in a six-year period has been made to obtain trends for each safety indicator. An overview of the trends of the plant operational data during the same period are also provided and discussed. On the whole, the trends of safety indicators are improving during the observed period 1991-1996. The plant operational data have depicted coherent improvement with the safety indicator trends. This result supports the premise that improvements in safety performance and in operational reliability are correspondingly inter-dependent. Both the safety indicators quarterly report and the annual report are available to the public. The public can also approach this information from the AEC's World Wide Web site (http://www.aec.gov.tw).

INTRODUCTION

In recent years, the value of experience in improving and assuring the safety, reliability, and economics of commercial nuclear power plants has been seriously considered. It is recognized that the consequences of not understanding and applying the lessons of experience are just too great. Accordingly, Taiwan is also increasing its efforts to obtain feedback from the operational experience at its own plants and to learn from the experiences of others. The safety indicators program is one of the methods that the Atomic Energy Council (AEC) uses to obtain operational experience feedback.

In order to understand safety performance trending of nuclear power plants, the AEC, by referring to the USNRC's Performance Indicator Program, developed a safety indicators program since 1989. The safety indicators program provides an additional view of operational performance and enhances the AEC's ability to recognize areas of poor and/or declining safety performance of operating plants. However, it is just a tool and is to be used in conjunction with other tools such as the results of periodical (e.g. during refueling outages), resident and special inspections. The safety indicators program monitors trends in overall safety performance for a given plant and is intended to be one of several tools used by the AEC management in decision making regarding plant-specific regulatory programs.

Originally, there were eight indicators in this program. Since August 1993, AEC has added two more indicators, i.e. items nine and ten, to this program. Therefore, there are currently ten indicators monitored in this program. They are as follows: (1) automatic scrams while critical, (2) safety system actuations, (3) significant events, (4) safety system failures, (5) forced outage rate, (6) equipment forced outages per 1,000 critical hours, (7) collective radiation exposure, (8) volume of low-level solid radioactive waste, (9) fuel reliability, and (10) chemistry index.

Within the AEC, the focal point for the collection, assessment, and feedback of the safety indicators data is the Nuclear Technology Department (NTD). The NTD was established in February 1993 and one of its missions is to identify and provide feedback regarding safety-significant lessons of operational experience to other AEC activities and the plant licensee. The safety indicators are extracted from licensee reportable event reports, immediate telephone notifications, monthly operating reports, monthly performance indicator reports and AEC's resident inspection reports. Each quarter the AEC issues a safety indicators quarterly report and every year the AEC issues a safety indicators annual report. Both the safety indicators quarterly report and the annual report are made available to the public. The public can also obtain this information from the AEC's World Wide Web site (http://www.aec.gov.tw).

OPERATIONAL EXPERIENCE

Currently, there are three nuclear power plants (NPPs), with a total of six units, operating in Taiwan, namely Chinshan, Kuosheng and Mannshan NPPs. Four of these six units (Chinshan, twin units and Kuosheng, twin units) are BWRs, and the Mannshan twin units are PWRs.

The Chinshan Nuclear Power Plant (CSNPP) which is located at Shih-Men, about 28 kilometres northeast of Taipei, is a twin-unit plant with GE BWR-4 reactors and the Mark 1 containment design. Each of its turbine generators is rated at 636 MWe. The Kuosheng Nuclear Power Plant (KSNPP) which is located at Wan-li, about 22 kilometres northeast of Taipei, has twin-unit GE BWR-6 reactors and the Mark-3 containment design. Each turbine generator is rated at 985 MWe. Both CSNPP and KSNPP are located on the coast of the East China Sea. The Mannshan Nuclear Power Plant (MSNPP) is located at Heng-Chung, near the southern tip of Taiwan. MSNPP is a twin-unit with a 3-loop Westinghouse PWR plant and each of its turbine generators is rated at 951 MWe. Other information for these NPPs is provided in Table 1.

These nuclear units are intended to be reliable and economic base-load units for supplying electricity in Taiwan. The net electricity generated from these six nuclear units accounted for about 30% of the total electricity generated by Taipower's system in recent years. Figure 1 shows the installed nuclear capacity and nuclear share percentage in Taiwan from 1989 to 1996. Figure 1 indicates that since no new nuclear units have been added into the system, the installed nuclear capacity remains almost constant. While the total installed capacity is shown to be increasing, the nuclear share percentage is gradually decreasing. Therefore, maintaining Taiwan's nuclear power plants operating in a safe, stable and economic status is getting to be more critical. Figure 2 shows the annual capacity factor of the operating nuclear reactors. In fact, the average capacity factor has been greater than 70% since 1990, and in 1996 reached a yearly high of 83.6%.

DEFINITIONS OF THE SAFETY INDICATORS

1. Automatic Scrams While Critical (Scrams)

This indicator means that during the reactor critical operation condition, the reactor protection system unplanned actuation causes fast insertion of control rods into the core. This indicator is identical to the indicator, unplanned automatic scrams while critical, used by the Institute of Nuclear Power Operation (INPO).

2. Safety System Actuations (SSAs)

This indicator includes actual and inadvertent actuation of emergency core cooling systems, as well as actuation of the emergency AC power system (namely the emergency diesel generator) due to loss of power to a vital bus.

3. Significant Events (SE)

These events are identified through detailed screening of operating experience by the Nuclear Technology Department of the Atomic Energy Council, and includes degradation of important safety equipment, unexpected plant response to a transient or a major transient, discovery of a major condition not considered in the plant safety analysis, and degradation of fuel integrity, primary coolant pressure boundary, or important associated structures.

4. Safety System Failure (SSF)

This indicator includes any event or condition that alone could prevent the fulfillment of the safety function of structures or systems. The safety system shown in this indicator is not the same as the safety system shown in the SSA indicator. There are 18 to 19 systems or subsystems that are monitored for this indicator.

5. Forced Outage Rate (FOR)

This indicator‘s definition is identical to the one used by USNRC (R.G.1.16). It is the number of forced outage hours divided by the sum of forced hours and generator on-line hours.

6. Equipment Forced Outages per 1000 Critical Hours (EFO)

The indicator is the inverse of the mean time between forced outages caused by equipment. The mean time is equal to the number of hours the reactor is critical in a period divided by the number of forced outages caused by equipment failures during that period.

7. Collective Radiation Exposure

The indicator is the total external whole-body dose received by all on-site personnel (including contractors and visitors) during a time period, as measured by the primary dosimeter, thermoluminescent dosimeter (TLD) or film badge. It is the total dose at the station. The station total is divided by the number of contributing units at the site to obtain unit values.

8. Volume of Low-Level Solid Radioactive Waste

This indicator is defined as the volume of low-level solid radioactive waste that has been processed and is in final form (e.g. compacted or solidified) ready for disposal (burial or permanent storage), during a given period. It is calculated using the amount of waste in final form, including the container, actually shipped for disposal from both on-site and off-site facilities, plus the change in inventory of final-form waste in storage at both on-site and off-site facilities. Low-level refers to all radioactive waste that is not spent fuel or a by-product of spent fuel processing.

9. Fuel Reliability

This indicator is identical to the indicator used by the World Association of Nuclear Operators (WANO). Fuel reliability is inferred from fission product activities present in the reactor coolant. Due to design differences, this indicator is calculated differently for different reactor types. For BWRs, the indicator is defined as the combined steady-state off-gas activity rate (microcuries/second) measured at the steam jet air ejector outlet for the six primary noble gas fission products, collected for the tramp uranium (recoil release) contribution and power level, and normalized to a common average linear heat generation rate (LHGR). For PWRs, the indicator is defined as the steady-state primary coolant iodine-131 activity (microcuries/gram), collected for the tramp uranium contribution and power level, and normalized to a common purification rate.

10. Chemistry Index

The chemistry index compares selected parameters to the limiting values for those parameters. Each parameter value is divided by the limiting value for the parameter, and the sum of these ratios is normalized to 1.0. The limiting values are the “achievable values” defined by international industry-accepted values. Due to design differences, this indicator is calculated differently, and is present separately for several plant categories based on the reactor type, the type of steam generator, and the method of pH control.

DISCUSSION AND CONCLUSIONS

The results of an analysis of the data obtained from 1991 to 1996 are summarized in Table 2 and in

Figures 3 to 11. The table and figures present the average values of the ten SIs. This analysis has resulted in the following conclusions:

1. The annual automatic scram frequency decreased from twice per unit per year to once per unit per year.
2. The SSA frequency remained 1.83 per unit for two years; it still has room for improvement.
3. The SE frequency remains pretty low, and the main causes are from human error.
4. The SSF frequency decreased from 2-3 times per unit to 1-2 times per unit.
5. The FOR is in the range of 2.0% to 3.5%, well below the industry-wide average.
6. The EFO per 1000 critical hours is still unstable, however in 1996 reached its best value of 0.18.
7. The annual dose rates keep decreasing for both BWR and PWR plants.
8. The volume of solid radioactive waste is upgrading for both BWR and PWR plants.
9. The chemistry index also shows improvement.
10. The fuel reliability indicated that Chinshan NPP's fuel leakage occurred in 1992 and Kuosheng NPP's fuel leakage occurred in 1995.

Generally, during these years the safety performance trend for most SIs is improving. The capacity factor, one of the measures of plant operational reliability, also shows improvement and a similarity with the safety indicator trends. This observation supports the premise that improvements in safety performance and operational reliability are related.

REFERENCES

Lin, J.T. and Hsu, M.T., "Analysis of Reportable Event Reports of Taiwan's Nuclear Power Plants in 1996", May, 1997.

Hsu, M.T. and Lin, J.T., "Safety Indicators Annual Reports of Taiwan's Nuclear Power Plants in 1996", March, 1997.

KEY WORDS

Safety indicator, performance indicator, trend, experience feedback, operating data.

Table 1 Basic information of Taiwan's nuclear power plants

ITEM	CHINSHAN NPP	KUOSHENG NPP	MAANSHAN NPP
CONSTRUCTION START	#1 1970-11 #2 1970-11	#1 1974-09 #2 1974-09	#1 1978-01 #2 1978-01
COMMERCIAL OPERATION	#1 1978-12 #2 1979-07	#1 1981-12 #2 1983-03	#1 1984-07 #2 1985-05
REACTOR VENDOR	GE	GE	WESTINGHOUSE
GENERATOR VENDOR	WESTINGHOUSE	WESTINGHOUSE	GE
REACTOR TYPE	BWR-4	BWR-6	PWR(3-LOOP)
INSTALLED CAPACITY	636MWe 2	985MWe 2	951MWe 2
THERMAL POWER	1775MWt 2	2894MWt 2	2785MWt 2
OWNER	TAIWAN POWER COMPANY	TAIWAN POWER COMPANY	TAIWAN POWER COMPANY

Table 2 Safety indicators annual average from year 1991~1996

INDICATORS		1991	1992	1993	1994	1995	1996
AUTO SCRAMS (PER UNIT)		2.33	1.17	2.17	1.50	1.83	1.00
SSA (PER UNIT)		3	1.17	1.50	2.33	1.83	1.83
SE (PER UNIT)		0.67	0.33	0.50	0.00	0.33	0.33
SSF (PER UNIT)		3.83	2.00	2.33	1.50	2.50	1.33
FOR (% PER UNIT)		1.71	2.62	2.74	2.50	2.14	2.78
EFO (PER 1,000 CH PER UNIT)		0.27	0.25	0.37	0.39	0.46	0.18
ANNUAL RADIATION DOSE	BWR	3.7	3.44	3.12	3.14	2.55	2.79
(MAN ·Sv/UNIT)	PWR	0.84	1.67	1.27	0.76	1.13	0.58
SOLID RADWASTE	BWR	292.7	175	217	212.8	145.7	92.2
(M^3/UNIT)	PWR	59	38	53	50	44.9	40.4
FUEL RELIABILITY (*m* Ci/sec/UNIT)	BWR	1517	7354	34.4	36.7	143.91	5.67
(*m* Ci/gm /UNIT)	PWR	4.9E-05	3.2E-05	4.2E-05	3.4E-05	1.1E-06	1.0E-06
CHEMISTRY INDEX	BWR	0.55	0.38	0.33	0.30	0.31	0.26
	PWR	0.33	0.18	0.14	0.18	0.19	0.18

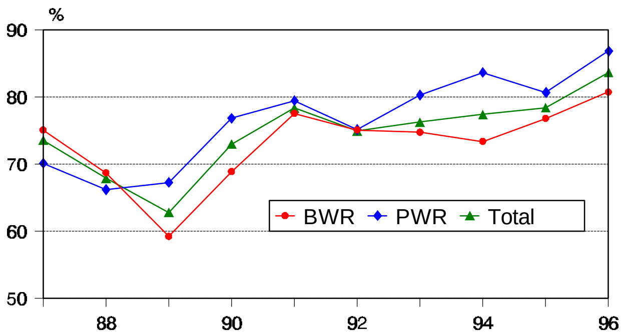

Figure 1 Annual capacity factor for the NPPs in Taiwan

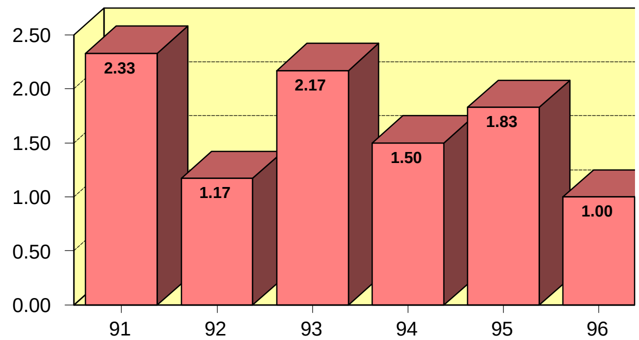

Figure 2 Nuclear share of electricity generation in Taiwan

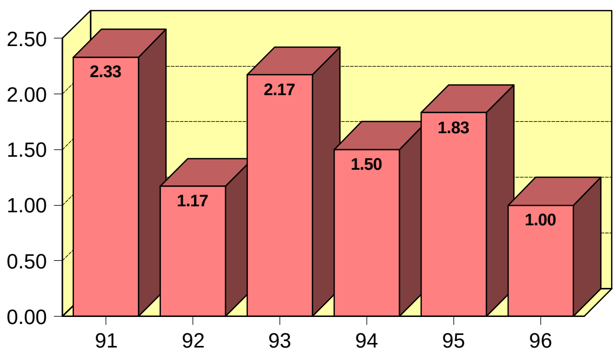

Figure 3 Automatic Scrams while critical

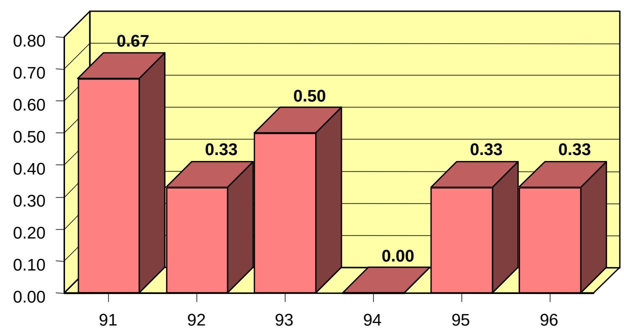

Figure 4 Safety System Actuations

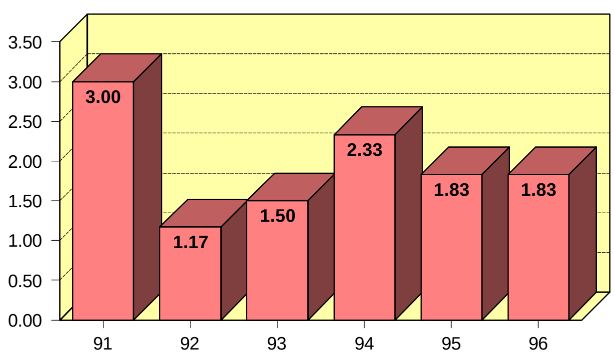

Figure 5 Significant Events

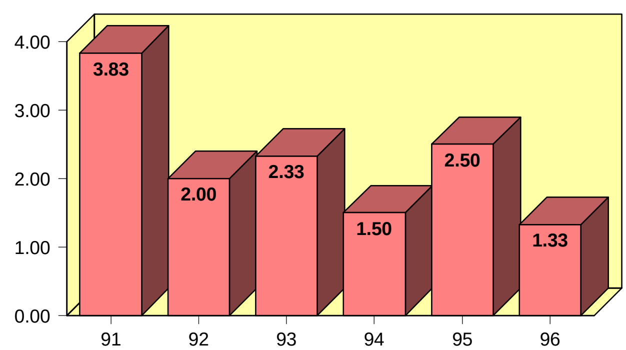

Figure 6 Safety System Failure

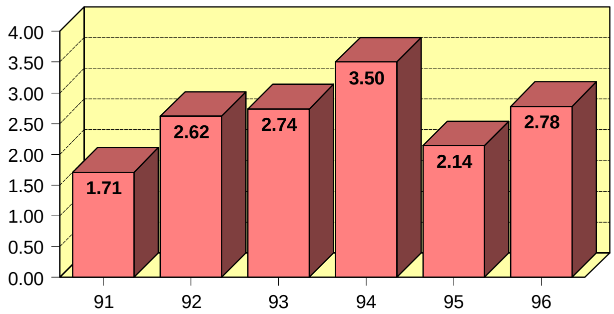

Figure 7 Forced Outage Rate

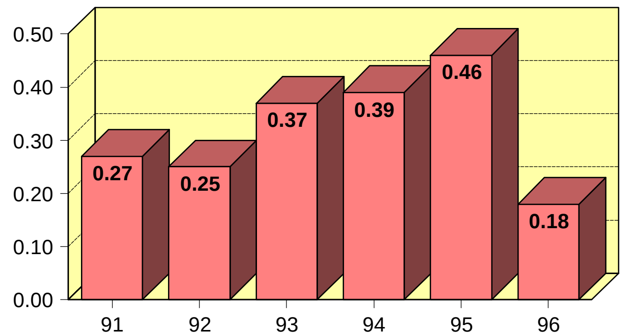

Figure 8 Equipment Forced Outages per 1000 Critical Hours

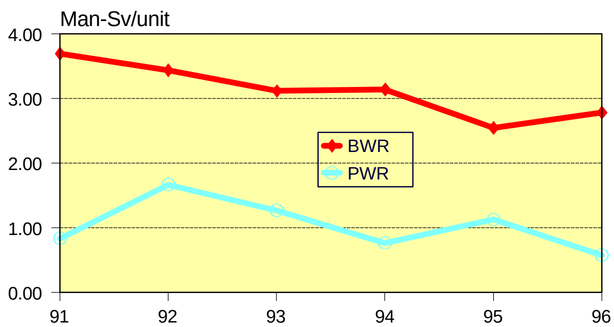

Figure 9 Annual Collective Radiation Exposure

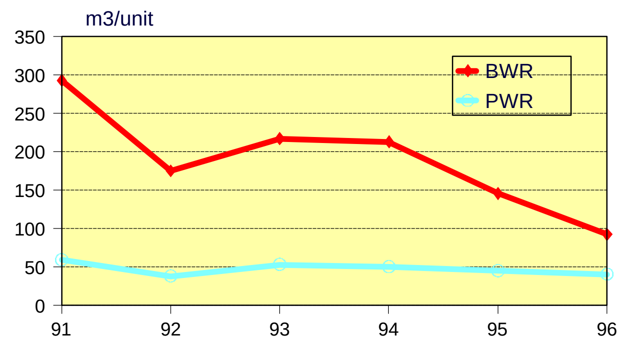

Figure 10 Volume of Low-Level Solid Radioactive Waste

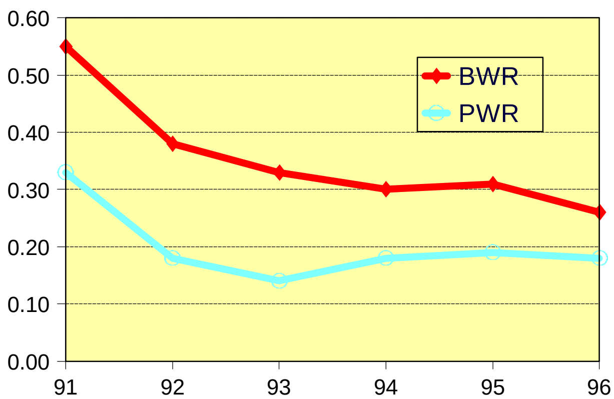

Figure 11 Chemistry Index