SUSQUEHANNA SES UNIT 2 CYCLE 6

STARTUP TEST SUMMARY

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Manager Nuclear Operations

ABSTRACT

Susquehanna Unit 2
Cycle 6
Startup Test Summary

Susquehanna Unit 2 resumed commercial operation for Cycle 6 on November 13, 1992 following a refueling and maintenance outage. The Unit 2 Cycle 6 (hereafter referred to as S2C6) reload included:

4	SPC	9 x 9	thrice burned*
88	SPC	9 x 9	thrice burned
204	SPC	9 x 9	twice burned
232	SPC	9 x 9	once burned
236	SPC	9 x 9	unirradiated fuel assemblies

*These 4 assemblies were discharged at EOC4 and are being reinserted to support an extended burnup program.

The following startup tests, identified in the S2C6 Reload Licensing Submittal, are discussed in this report:

1. Core Loading Verification
2. POWERPLEX Input Deck Validation
3. Control Rod Functional (Insert and Withdrawal Checks)
4. Subcritical Shutdown Margin Demonstration
5. In-Sequence Critical and Shutdown Margin Demonstration
6. Control Rod Scram Time Testing
7. Tip Asymmetry

In addition, the startup program included core flow and LPRM calibrations, thermal limits monitoring and baseline recirculation data acquisition. A summary of these activities is also included in this report.

Susquehanna Unit 2
Cycle 6
Startup Test No. 1
Core Verification and Audit

Purpose

The purpose of this test is to visually verify that the core is loaded per the analyzed designs.

Criteria

Upon completion of core alterations during the refueling outage, the core must be verified to conform with the reference core design used in the various licensing analyses. The verifications to be performed include fuel bundle location, fuel bundle orientation, and proper seating of the fuel bundles within the core. The verifications will be performed by the Reactor Engineering Group utilizing an underwater television camera. The verification will be videotaped so that an independent verification may be performed. Any discrepancies discovered in the loading will be promptly corrected and the affected bundles shall be reverified prior to unit startup.

Results

Susquehanna took the following precautions to prevent a misloaded fuel bundle. During the total core offload, bundles to be used next cycle were placed in the pool in the order in which they were to be reloaded. This facilitated an orderly stripping of bundles during the reload. After the offload was complete, a serial number verification of these bundles was performed (10/2/92) prior to reload. The core reload was performed in three parts. First, the irradiated bundles were loaded and a partial core verification serial number, location, orientation and height check was performed on 10/15/92. Second, the first batch of new fuel, 88 bundles (3.40 wt % U-235, 10 GD5), was loaded and a location check was performed. Third, the remaining new fuel, 148 bundles (3.51 wt %, 9 GD4) was loaded.

The Cycle 6 final core verification consisted of two videotaped passes over the core. During the first pass, the fuel bundle serial numbers were recorded on the videotape to verify proper location. The second pass was performed to verify proper fuel assembly seating (assembly height check) and correct orientation.

The core tapes were independently verified to be correct by a member of the Reactor Engineering Group and a representative of Quality Control on 10/17/92. Therefore, the as-loaded core configuration is consistent with the core design Siemens Nuclear Power and PP&L used in the evaluation of the S2C6 Reload Licensing Analyses. The S2C6 core map is included as Figure 1.

C R E A T E   M O D E   S S E S   U N I T - 2 / C Y C L E - 6

CYCLE(6) CALCULATED FULL CORE LOADING PATTERN

PREPARED BY/DATE: Edward a [signature] 6-2-92

REVIEWED BY/DATE: Andrew [signature] 6/5/92

APPROVED BY/DATE: [signature] 6/9/92

RECEIVED BY/DATE (SUPV REACT ENGRG): J R Dorsey 6/12/92

GE-Y/GE-X:	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29
60									X22487	X22483	X22479	X22387	X22379	X22341	X22368
58								X22495	X24905	X24929	X24881	X24969	X24909	X24953	X24885
56						X22371	X22389	X24861	X24837	X23653	S25145	X23581	S25141	X23673	S25137
54						X22335	X24985	X24781	X23721	S25233	X24965	S25229	X24925	S25225	X23625
52					X23617	X24949	X23705	X24977	S25133	X24941	S25221	X24809	S25217	X24849	S25129
50			X22360	X22351	X24877	S25125	X24957	S25213	X23701	S25121	X23757	S25209	X23689	S25117	X23601
48			X22380	X24921	X23669	X24773	S25205	X24765	S25201	X24829	X24845	X23605	S25113	X24817	X23645
46		X22350	X24981	X24865	X24769	S25197	X24797	S25193	X23609	S25189	X23733	S25109	X23681	S25105	X23621
44	X22480	X24901	X24813	X23729	S25101	X23709	S25185	X23633	S25181	X24833	S25097	X24893	S25093	X23665	S25089
42	X22465	X24993	X23593	S25177	X24789	S25085	X24825	S25173	X24945	S25169	X23713	X23737	X23649	S25081	X24933
40	X22467	X24853	S25077	X24821	S25165	X23753	X24841	X23741	S25073	X23749	S25069	X24873	S25065	X24805	X23677
38	X22342	X24793	X23637	S25161	X24913	S25157	X23585	S25061	X24897	X23685	X24889	X23761	X23561	S25057	X23589
36	X22388	X24777	S25053	X24961	S25153	X23717	S25049	X23697	S25045	X23597	S25041	X23577	X23629	X24973	S25037
34	X22325	X24917	X23693	S25149	X24869	S25033	X24989	S25029	X23745	S25025	X24801	S25021	X24937	S25017	X23657
32	X22343	X24785	S25013	X23613	S25009	X23573	X23565	X23569	S25005	X24857	X23725	X23641	S25001	X23661	X21037
30	X22443	X24788	S25016	X23616	S25012	X23576	X23568	X23572	S25008	X24860	X23728	X23644	S25004	X23664	X21287
28	X22463	X24920	X23696	S25152	X24872	S25036	X24992	S25032	X23748	S25028	X24804	S25024	X24940	S25020	X23660
26	X22398	X24780	S25056	X24964	S25156	X23720	S25052	X23700	S25048	X23600	S25044	X23580	X23632	X24976	S25040
24	X22442	X24796	X23640	S25164	X24916	S25160	X23588	S25064	X24900	X23688	X24892	X23764	X23564	S25060	X23592
22	X22555	X24856	S25080	X24824	S25168	X23756	X24844	X23744	S25076	X23752	S25072	X24876	S25068	X24808	X23680
20	X22553	X24996	X23596	S25180	X24792	S25088	X24828	S25176	X24948	S25172	X23716	X23740	X23652	S25084	X24936
18	X22544	X24904	X24816	X23732	S25104	X23712	S25188	X23636	S25184	X24836	S25100	X24896	S25096	X23668	S25092
16		X22436	X24984	X24868	X24772	S25200	X24800	S25196	X23612	S25192	X23736	S25112	X23684	S25108	X23624
14			X22406	X24924	X23672	X24776	S25208	X24768	S25204	X24832	X24848	X23608	S25116	X24820	X23648
12			X22424	X22437	X24880	S25128	X24960	S25216	X23704	S25124	X23760	S25212	X23692	S25120	X23604
10					X23620	X24952	X23708	X24980	S25136	X24944	S25224	X24812	S25220	X24852	S25132
8						X22451	X24988	X24784	X23724	S25236	X24968	S25232	X24928	S25228	X23628
6						X22417	X22399	X24864	X24840	X23656	S25148	X23584	S25144	X23676	S25140
4								X22527	X24908	X24932	X24884	X24972	X24912	X24956	X24888
2									X22535	X22539	X22543	X22397	X22405	X22441	X22414

FIGURE 1

CREATE MODE SSES UNIT-2/CYCLE-6

CYCLE(6) CALCULATED FULL CORE LOADING PATTERN

PREPARED BY/DATE: [signature] 6-2-92 REVIEWED BY/DATE: [signature] 6/5/92 APPROVED BY/DATE: [signature] 6/9/92
RECEIVED BY/DATE (SUPV REACT ENGRG): [signature] 6/12/92

GE-Y/GE-X:	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59
60	X22375	X22348	X22384	X22392	X22482	X22486	X22490								
58	X24886	X24954	X24910	X24970	X24882	X24930	X24906	X22498							
56	S25138	X23674	S25142	X23582	S25146	X23654	X24838	X24862	X22390	X22372					
54	X23626	S25226	X24926	S25230	X24966	S25234	X23722	X24782	X24986	X22338					
52	S25130	X24850	S25218	X24810	S25222	X24942	S25134	X24978	X23706	X24950	X23618				
50	X23602	S25118	X23690	S25210	X23758	S25122	X23702	S25214	X24958	S25126	X24878	X22352	X22365		
48	X23646	X24818	S25114	X23606	X24846	X24830	S25202	X24766	S25206	X24774	X23670	X24922	X22383		
46	X23622	S25106	X23682	S25110	X23734	S25190	X23610	S25194	X24798	S25198	X24770	X24866	X24982	X22353	
44	S25090	X23666	S25094	X24894	S25098	X24834	S25182	X23634	S25186	X23710	S25102	X23730	X24814	X24902	X22481
42	X24934	S25082	X23650	X23738	X23714	S25170	X24946	S25174	X24826	S25086	X24790	S25178	X23594	X24994	X22472
40	X23678	X24806	S25066	X24874	S25070	X23750	S25074	X23742	X24842	X23754	S25166	X24822	S25078	X24854	X22470
38	X23590	S25058	X23562	X23762	X24890	X23686	X24898	S25062	X23586	S25158	X24914	S25162	X23638	X24794	X22347
36	S25038	X24974	X23630	X23578	S25042	X23598	S25046	X23698	S25050	X23718	S25154	X24962	S25054	X24778	X22391
34	X23658	S25018	X24938	S25022	X24802	S25026	X23746	S25030	X24990	S25034	X24870	S25150	X23694	X24918	X22326
32	X21038	X23662	S25002	X23642	X23726	X24858	S25006	X23570	X23566	X23574	S25010	X23614	S25014	X24786	X22346
30	X21288	X23663	S25003	X23643	X23727	X24859	S25007	X23571	X23567	X23575	S25011	X23615	S25015	X24787	X22446
28	X23659	S25019	X24939	S25023	X24803	S25027	X23747	S25031	X24991	S25035	X24871	S25151	X23695	X24919	X22464
26	S25039	X24975	X23631	X23579	S25043	X23599	S25047	X23699	S25051	X23719	S25155	X24963	S25055	X24779	X22401
24	X23591	S25059	X23563	X23763	X24891	X23687	X24899	S25063	X23587	S25159	X24915	S25163	X23639	X24795	X22447
22	X23679	X24807	S25067	X24875	S25071	X23751	S25075	X23743	X24843	X23755	S25167	X24823	S25079	X24855	X22558
20	X24935	S25083	X23651	X23739	X23715	S25171	X24947	S25175	X24827	S25087	X24791	S25179	X23595	X24995	X22560
18	S25091	X23667	S25095	X24895	S25099	X24835	S25183	X23635	S25187	X23711	S25103	X23731	X24815	X24903	X22545
16	X23623	S25107	X23683	S25111	X23735	S25191	X23611	S25195	X24799	S25199	X24771	X24867	X24983	X22439	
14	X23647	X24819	S25115	X23607	X24847	X24831	S25203	X24767	S25207	X24775	X23671	X24923	X22409		
12	X23603	S25119	X23691	S25211	X23759	S25123	X23703	S25215	X24959	S25127	X24879	X22438	X22429		
10	S25131	X24851	S25219	X24811	S25223	X24943	S25135	X24979	X23707	X24951	X23619				
8	X23627	S25227	X24927	S25231	X24967	S25235	X23723	X24783	X24987	X22454					
6	S25139	X23675	S25143	X23583	S25147	X23655	X24839	X24863	X22400	X22418					
4	X24887	X24955	X24911	X24971	X24883	X24931	X24907	X22530							
2	X22421	X22448	X22410	X22402	X22546	X22542	X22538								

CLASP CYCLE 6 FULL CORE LOADING PATTERN SAVED AS CASE# 26.

FIGURE 1 (CONTINUED)

Susquehanna Unit 2
Cycle 6
Startup Test No. 2
POWERPLEX Input Deck Validation

__Purpose__

To ensure the POWERPLEX input deck is updated correctly before the start of every new fuel cycle.

__Criteria__

POWERPLEX is the Siemens (formerly ANF) software system designed to perform in-core monitoring of BWR cores. Core monitoring is performed by the module, XTGBWR, a three-dimensional reactor simulator code which calculates bundle nodal powers. The POWERPLEX input deck consists of all constants needed for the execution of this code and subsequent calculation of the margin to thermal limits. These constants must be updated prior to the start of every new fuel cycle in order to ensure satisfactory core monitoring of the new core configuration. The deck is generated by Nuclear Fuels Engineering and validated/verified by members of the Reactor Engineering Group at Susquehanna.

__Results__

The POWERPLEX input deck was completely reviewed, all comments resolved, verified to be correct and successfully loaded into the POWERPLEX system prior to S2C6 startup.

Susquehanna Unit 2
Cycle 6
Startup Test No. 3
Control Rod Functional (Insert and Withdrawal Checks)

Purpose

The purpose of this startup test is to assure proper control rod function and demonstrate that criticality will not occur due to the withdrawal of a single rod.

Criteria

Control Rod Functionals include mobility, overtravel and subcritical checks. These may be performed as each control cell is loaded in its final configuration.

Each control rod will be cycled individually to ensure mobility. As each rod is fully withdrawn, it will be checked for overtravel by continually applying a withdrawal signal. Subcriticality will also be verified with the rod withdrawn.

Results

Control Rod Functionals were commenced after the core was fully loaded and verified. No control rods overtraveled and subcriticality was maintained as each rod was individually fully withdrawn and reinserted.

Susquehanna Unit 2
Cycle 6
Startup Test No. 4
Subcritical Shutdown Margin Demonstration

Purpose

The purpose of this startup test is to assure at least the minimum required shutdown margin exists with the strongest worth control rod fully withdrawn.

Criteria

The minimum required shutdown margin at BOC for Susquehanna Unit 2 Cycle 6 is 0.38% Δ K/K. This test will verify at least this amount by performance of a subcritical shutdown margin demonstration. The highest (strongest) worth control rod is fully withdrawn, then a diagonally adjacent rod is slowly notched out verifying subcriticality at each step until the analytically determined reactivity worth of the control rods at their respective notch position equals or slightly exceeds the required amount of SDM.

Results

The reactor remained subcritical with the highest worth control rod fully withdrawn and an additional diagonally adjacent rod pulled to a notch position with a calculated worth of 1.309% Δ K/K. The required shutdown margin to be demonstrated was calculated to be 0.4913% Δ K/K. This is 0.38% Δ K/K plus a correction factor for the recirculation loop (moderator) temperature (102 degrees F) at the time of the test. Using data supplied by Nuclear Fuels Engineering it was determined that the following rods pulled to the indicated position would demonstrate a shutdown margin of 1.198% Δ K/K.

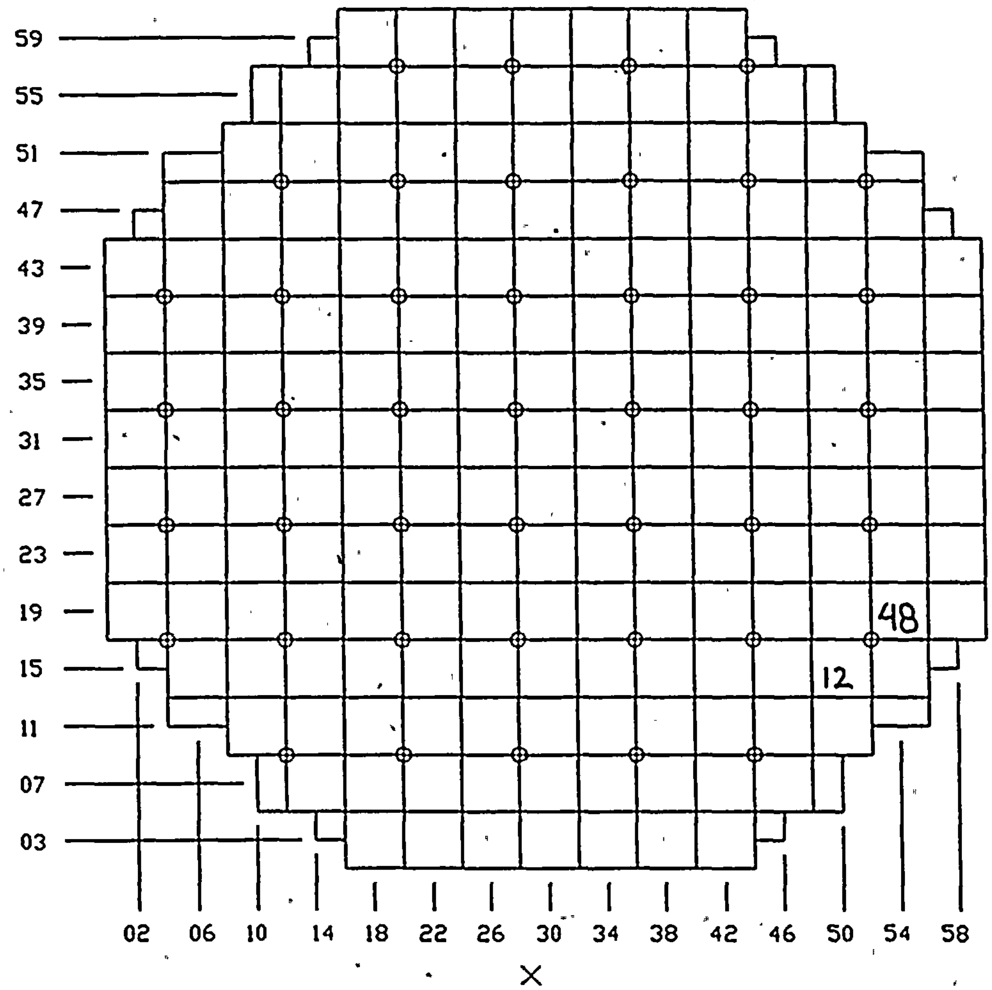
ROD	POSITION	TOTAL WORTH % Δ K/K
54-19*	48	--
50-15	12	1.309

*analytically determined strongest rod.

As rods were pulled, subcritiality was verified after each notch. Subcriticality was also verified with the rods at the above indicated positions, thus satisfying the purpose of this startup test. Figure 2 is a core map showing the test rod positions.

FIGURE 2

CORE MAP SHOWING TEST ROD POSITIONS
FOR
SUBCRITICAL SHUTDOWN MARGIN DEMONSTRATION



BLANKS INDICATE RODS AT 00

Susquehanna Unit 2
Cycle 6
Startup Test No. 5
In-Sequence Critical and SDM Determination

Purpose

The purpose of this startup test is to calculate the actual shutdown margin of the Cycle 6 core and to demonstrate that no reactivity anomaly exists.

Criteria

1) Shutdown Margin

Technical Specification 3.1.1 requires an adequate shutdown margin to ensure the reactor can be made subcritical from all operating conditions. This value, 0.38% Δ K/K has been determined to be the minimum required SDM to bring a reactor subcritical under the worst case conditions - a cold, xenon-free core at the most reactive point in the cycle with the highest worth control rod unavailable for reactivity control. At beginning of cycle, the required SDM value must be increased by a factor, R, if it is determined that core shutdown margin is less at a point in the cycle other than the initial shutdown margin (for Cycle 6, R = 0% Δ K/K). The required beginning-of-cycle SDM for Susquehanna Unit 2 Cycle 6 is 0.38% Δ K/K; the actual SDM will be calculated from data obtained during the initial startup criticality.

2) Reactivity Anomaly

Core reactivity is monitored to prevent excessive reactivity additions due to unforeseen reactivity changes or reactivity anomalies. At BOC, a 1% Δ K/K difference between predicted and actual critical control rod positions might indicate improper core loading or a computer code that is unreliable. Data gathered during the in-sequence critical, specifically the Keff at the notch position of the control rod at which criticality occurs, is compared to predicted critical control rod position Keff and a % reactivity difference is calculated.

Results

The calculated SDM was 1.7678% Δ K/K and the difference between actual Keff and predicted Keff at criticality was - 0.014% Δ K/K.

Control rods were withdrawn in the B sequence until the reactor was on a stable, positive period. Criticality occurred on rod 22-15 at notch 18, which was step 34 of the startup sequence. A special log was initiated to record SRM count rates and recirculation loop temperatures. The average period was 168.5 seconds and the average loop temperature 139.0 degrees F which yield period and temperature corrections of .366 x 10^{-3} Δ K/K and 2.93 x 10^{-3} Δ K/K, respectively.

1) Shutdown Margin

The equation used to calculate SDM

$$SDM = \frac{Kcrit - Ksro}{Kcrit * Ksro} - \Delta p \text{ (period)} - \Delta p \text{ (temp)}$$

Kcrit is Keff at the actual critical control rod position (1.00317) and Ksro is Keff predicted with the strongest rod out (0.982495).

The minimum required SDM for Unit 2 Cycle 6 at beginning of cycle was 0.38% Δ K/K; the calculated shutdown margin based on this test was 1.7678% Δ K/K, thus satisfying the acceptance criteria.

2) Reactivity Anomaly

The reactor went critical at step 34 with Kcrit of 1.00317. The equation used to calculate reactivity difference was

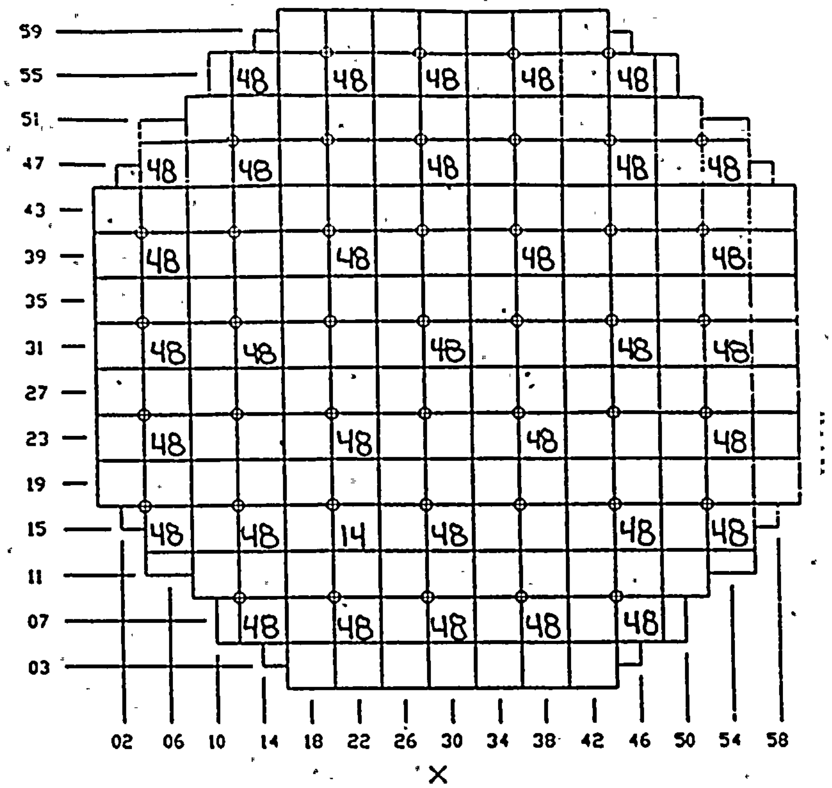
$$\text{Reactivity difference} = \frac{Kcrit - 1}{Kcrit} - \Delta p \text{ (period)} - \Delta p \text{ (temp)}$$

The calculated reactivity difference was -0.014% Δ K/K. This satisfies ± 1% Δ K/K acceptance criteria.

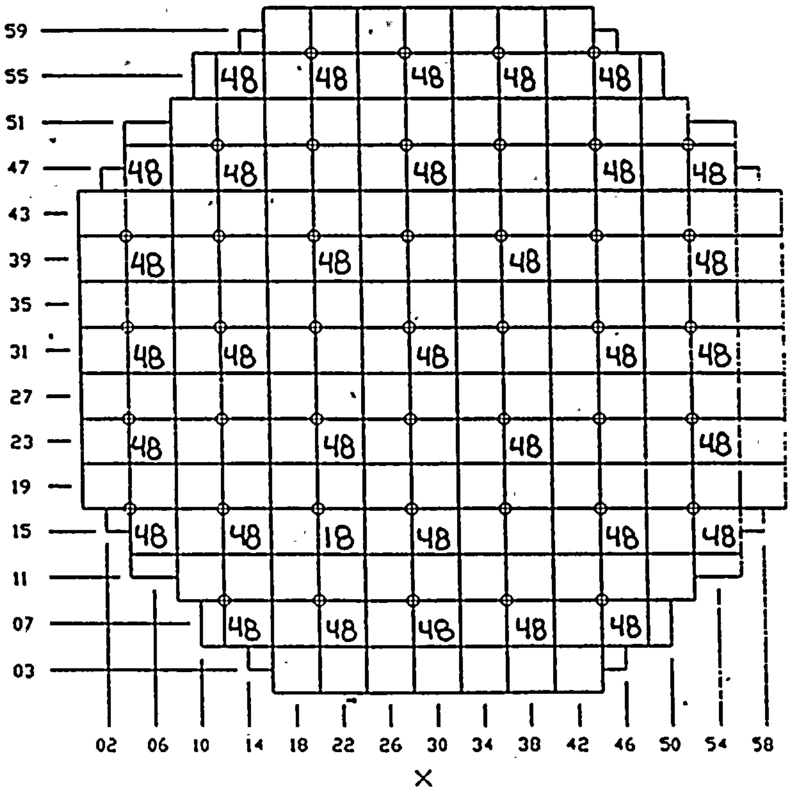
A comparison of the predicted versus actual critical control rod patterns is included as Figure 3.

FIGURE 3

COMPARISON OF PREDICTED VS AUTUAL CRITICAL ROD PATTERNS



PREDICATED CRITICAL PATTERN



ACTUAL CRITICAL PATTERN

BLANKS INDICATE RODS AT 00

Susquehanna Unit 2
Cycle 6
Startup Test No. 6
Control Rod Scram Time Testing

Purpose

To demonstrate the maximum scram insertion times of all rods following core alterations.

Criteria

Susquehanna Technical Specification 4.1.3.2 states that scram insertion times of all control rods shall be demonstrated through measurement with reactor coolant pressure greater than 950 psig prior to exceeding 40% thermal power after core alterations. For Unit 2 Cycle 6 approximately one-half of all control rod scram times were to be determined by performing a black-and-white scram from the B sequence and using GETARS scram data. The remaining rods were to be individually scram time tested.

Results

Control rod scram times for 97 rods were obtained through GETARS from the black-and-white scram performed 11/9/92 (B sequence). The remaining rods were individually scram timed on 11/15-16/92. All scram times were within the acceptance criteria, as shown in Table 1.

	ROD	ROD POSITION	TIME AS FOUND	T.S. LIMIT
MAXIMUM INDIVIDUAL ROD SCRAM INSERTION TIME T.S. 3.1.3.2	14-31	5	3.11	7.0
AVERAGE SCRAM INSERTION TIME OF OPERABLE RODS T.S. 3.1.3.3		45 39 25 05	0.30 0.61 1.35 2.45	0.43 0.86 1.93 3.49
AVERAGE SCRAM INSERTION TIME OF SLOWEST 2x2 ARRAY T.S. 3.1.3.4		45 39 25 05	0.31 0.66 1.47 2.68	0.45 0.92 2.05 3.70

TABLE 1: Results of Scram Time Testing of All Control Rods S2C6.

Susquehanna Unit 2
Cycle 6
Startup Test No. 7
TIP Asymmetry

Purpose

The purpose of this test is to check core symmetry by performing a statistical uncertainty analysis on the Traversing In-Core Probe (TIP) System. Also, by the performance of this test, the proper operation of the TIP system will be assured.

Criteria

The X^2 test of significance will be performed with the significance level fixed at 1%. The test will be performed utilizing an octant symmetric rod pattern at a power level greater than 75% of rated power. The startup test criteria for symmetric TIP differences is that the X^2 value calculated shall be less than the critical X^2 value. Since Susquehanna has 19 symmetric TIP pairs, the calculated X^2 value must be less than a critical X^2 value of 36.19 (as determined by Siemens). If the calculated X^2 value exceeds the critical value, the instrumentation and data processing system should be reviewed for any problems which may contribute to abnormal TIP asymmetries. A second determination of X^2 should then be made. If the new measured value of X^2 exceeds the critical value, Nuclear Fuels Engineering shall be consulted and appropriate action taken to assure that a larger than anticipated TIP asymmetry does not adversely affect the safe operation of the reactor.

Results

A complete set of TIP data was obtained at the completion of Susquehanna Unit 2 BOC6 Startup Testing Program at rated thermal power. The nodal TIP values (Nodes 3 through 22) were summed up for each symmetric TIP pair using equation 5.1 with the results summarized in Table 2. Using Equations 5.2 and 5.3, the variance and X^2 were calculated to be 4.24 and 2.24 respectively. The X^2 value of 2.24 is well within the 36.19 limit established by Siemens (Formerly ANF).

Table 1
Absolute Relative Difference

Symmetric TIP Pair	Absolute Relative Difference dm
1	-2.87
2	0.13
3	-1.21
4	-2.08
5	2.69
6	1.97
7	-0.50
8	-0.21
9	0.40
10	-0.62
11	-0.18
12	4.20
13	1.45
14	-1.02
15	6.24
16	2.38
17	2.98
18	-4.76
19	-6.17

Equation 5.1

$$dm = \frac{100\ (Tm1 - Tm2)}{\frac{Tm1 + Tm2}{2}}$$

Note: $Tm1 = \sum_{K-3}^{22} T(k)$ for TIP1 and $Tm2 = \sum_{K-3}^{22} t(k)$ for TIP2

where TIP1 and TIP2 are symmetric TIP pairs

Equation 5.2 (Variance)

$$S^2TIPij = \sum_{M=1}^{19} \frac{dm^2}{38} = 4.24$$

Equation 5.3

$$X^2 = \frac{19\ S^2TIPij}{36} = 2.24$$

Susquehanna Unit 2
Cycle 6
Startup Program Summary

The following is a short summary of additional Reactor Engineering activities performed during the Startup Testing Program.

Thermal Limit Monitoring

Thermal Limits were checked throughout the startup period through review of the POWERPLEX core monitoring program, MONITOR, output. At no time did thermal limits exceed Technical Specification limits.

TIP System - OD-1 Performance

A full set of TIPS was run at 38% power to update the core power distribution before the first core performance calculation, MONITOR, was initiated. Subsequent TIP sets were performed at 60% and 100% power in conjunction with two LPRM calibrations. The LPRM currents were updated and the LPRM GAFS found to be within the acceptable range.

Power Distribution Comparison with Offline Monitoring

Favorable results were obtained when actual core power distribution data was compared to SIMULATE-E/PPL core modelling code data. The SIMULATE-E/PPL code is used by the Nuclear Fuels core management engineer to predict power TIP response distributions throughout the cycle. This comparison is included as Figure 4.

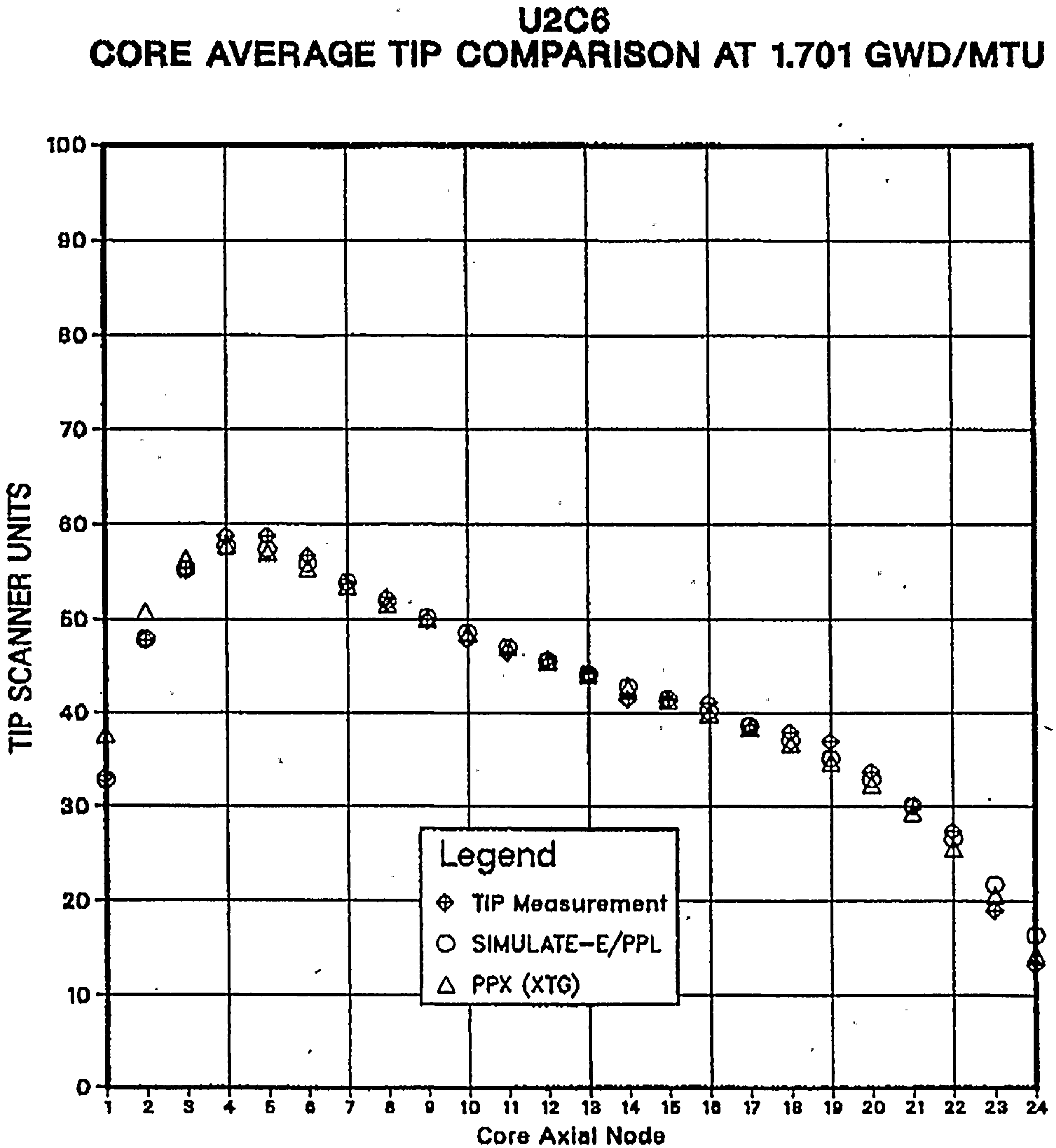
Core Flow Calibration

A core flow calibration was performed at 98.9% core flow. No adjustments to the jet pump and recirculation loop flow instrumentation were required.

Recirculation Loop Baseline Data Acquisition

Recirculation loop data was collected throughout the startup program to provide baseline data for plant performance monitoring in two loop operation. This data is used throughout the cycle during the performance of the Technical Specification Jet Pump Operability Surveillance.

FIGURE 4


U2C6
CORE AVERAGE TIP COMPARISON AT 1.701 GWD/MTU
TIP SCANNER UNITS
0
10
20
30
40
50
60
70
80
90
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Core Axial Node
Legend
TIP Measurement
SIMULATE-E/PPL
PPX (XTG)