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NUCLEAR REGULATORY COMMISSION
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO CORE XVIII RELOAD

YANKEE ATOMIC ELECTRIC COMPANY

YANKEE NUCLEAR POWER STATION

DOCKET NO. 50-029

1.0 INTRODUCTION

By letter dated August 30, 1985, the Yankee Atomic Electric Company (YAEC) submitted a report entitled "Yankee Nuclear Power Station Core XVIII Performance Analysis" (YAEC-1496), which supports the Core XVIII operation and provides the basis for the Technical Specification changes necessary for Core XVIII operation, and the proposed Technical Specification changes.

Core XVIII consists of 40 fresh assemblies and 36 irradiated assemblies; the fresh assemblies are fabricated by Combustion Engineering and the irradiated assemblies were fabricated by Exxon Nuclear. All assemblies have an enrichment of 3.7 w/o U-235. The core average exposure for beginning-of-life Core XVIII is 6148 MWd/MTU compared to 6562 MWd/MTU for Core XVII. The full power lifetime of Core XVIII is estimated to be 14,000 MWd/MTU compared to 12,500 MWd/MTU for Core XVII. Methodology used for Cycle XVIII analysis is consistent with the one used in Cycle XVII.

A preliminary examination of Core XVII during the outage indicated that there are some damaged rods among the core peripheral assemblies. This problem was initially discovered in Cycle XIV. The damage is similar to the baffle jetting problem discovered in some other Westinghouse reactors although the licensee maintained that the core designs were different between Yankee and those Westinghouse plants with the baffle jetting problem. The typical remedy to this problem is the replacement of damaged rods with solid Zircaloy (inert) rods. The licensee confirmed that some inert rods (less than 10) will be inserted into the core, which results in virtually no change to the current analysis and Technical Specification changes. Potential correction of the jetting problem was implemented during the outage by the installation of flow limiting plugs in the baffles.

An evaluation of the staff's review of the core XVIII analysis is provided in the following sections. The safety evaluation dealing with the technical specification amendment is being provided by separate correspondence.

2.0 LARGE BREAK LOCA ANALYSIS

2.1 Compliance of ECCS Evaluation Model to Appendix K

For the Core XVIII large break LOCA analysis, YAEC modified its currently approved ECCS evaluation model for Yankee. The specific model modification made was to reduce the ΔP penalty, which is utilized to account for steam - ECC water interaction effects during reflood, from 0.8 psid to 0.15 psid during the pumped ECC injection phase. The ΔP penalty during the accumulator injection phase was unchanged. Supporting documentation was provided in references 2 and 3.

In reference 4, the staff provided its evaluation of the modification to the ECCS evaluation model. We concluded that the model modification satisfied the requirements of Section I.D.4 of Appendix K to 10 CFR Part 50. Thus, the ECCS evaluation model utilized for the Core XVIII large break LOCA analysis is an approved evaluation model and complies with the requirements of Appendix K to 10 CFR Part 50.

2.2 Large Break LOCA Analysis

With respect to the large break LOCA analysis for Yankee, the licensee addressed the following items:

1) Core inlet temperature increase to 520°F
2) Lowering of the low pressure SIAS to 1650 psig
3) Axial power shape sensitivity
4) Burnup sensitivity analyses

Each of these items is addressed below in separate sections.

2.2.1 Core Inlet Temperature Increase

As part of the Core XVIII submittal of reference 1, the licensee proposed to modify Technical Specification 3.2.4, entitled Power Distribution Limits, DNB Parameters, by increasing the maximum allowable core inlet temperature, from its previous value of 515°F, to 520°F. The effect of raising the core inlet temperature was evaluated by the licensee by performing sensitivity analyses.

The licensee performed two large break LOCA calculations using core inlet temperatures of 519°F and 524°F. Consistent with the current methodology for Yankee, the inlet temperatures were increased 4°F above the maximum allowable values in order to account for uncertainties. The results of the two calculations showed that the inlet temperature of 519°F produced the higher peak cladding temperatures. Based upon these results, the licensee decided to perform all the large break LOCA calculations for Core XVIII using an inlet temperature of 519°F.

Based upon the results of the licensee's sensitivity study, we have concluded that use of a core inlet temperature of 519°F is conservative. Thus, the large break LOCA calculations discussed in Section 2.2.4, which were performed to demonstrate compliance with 10 CFR 50.46, supports the proposed Technical Specification change to increase the maximum core inlet temperature to 520°F.

2.2.2 SIAS Low Pressure Setpoint Decrease

For Core XVIII operation, the licensee proposed to decrease the Technical Specification value for the low pressure SIAS from 1700 psig to 1650 psig. This modification was proposed to avoid inadvertent Safety Injection actuations following a reactor trip.

The licensee evaluated the effect of this change on the Yankee large break LOCA analysis. In performing this assessment, a low pressure SIAS of 1600 psig was used to account for uncertainties. Because the initial depressurization during a large break LOCA results in an almost instantaneous generation of the SIAS, the licensee stated that the revised setpoint would not affect the analysis results. In addition, the licensee stated that the ECCS pump start time would be unaffected because it is based upon the emergency diesel start time upon loss of offsite power at time zero.

We have reviewed the licensee's statements and concur with the conclusions that lowering the low pressure SIAS would not affect the large break LOCA analysis. Thus, the proposed Technical Specification change is acceptable with respect to the Yankee large break LOCA analysis.

2.2.3 Axial Power Shape Sensitivity

Since 1975, Yankee LOCA analyses have been performed using a chopped cosine axial power distribution. In reference 5, the staff questioned the acceptability of using a chopped cosine axial power distribution for setting plant Technical Specifications.

Of specific concern was compliance with Section I.A of Appendix K to 10 CFR Part 50 which requires that "a range of power distribution shapes and peaking factors representing power distributions that may occur over the core lifetime shall be studied and the one selected shall be that which results in the more severe calculated consequences...."

To addresss the issue of compliance with Section I.A of Appendix K, the licensee performed axial power shape sensitivity studies for Core XVIII. The purpose of these studies was to define the methodology to be used for developing power shapes to use in generating the Technical Specification LHGR limits.

The licensee noted that during the first several months of plant operation, actual axial power shapes are closely approximated by a chopped cosine axial power distribution. However, after approximately 4 GWd/MTU, the axial power shape will become flatter and bottom-skewed. As a result of allowable control rod motion at full power, xenon transients can be induced which result in top-skewed axial power distributions.

To evaluate the effect of flux shape behavior on the large break LOCA analysis, the licensee performed two sensitivity analyses. First, a break spectrum evaluation was performed to assess the impact of axial power shape on the determination of the limiting break. Secondly, the licensee evaluated the effect of using a xenon transient induced top-skewed axial power shape.

With respect to defining the limiting break, previous Core XVI break spectrum analysis demonstrated that the limiting break for the chopped cosine axial power distribution was a double-ended cold leg guillotine break with a discharge coefficient of 0.8 (0.8 DECLG). The approved ECCS evaluation model used to determine the limiting break for Core XVI utilized the cold leg ΔP penalty 0.8 psid during the pumped ECC injection period.

Using a xenon transient induced top-skewed axial power shape, representative of end of cycle conditions, the licensee repeated the break spectrum analysis. For this study, the licensee utilized the approved ECCS evaluation model which has a cold leg ΔP penalty of 0.15 psid during the pumped ECC injection period. As a result of this study, the limiting break was determined to be a double-ended cold leg split with a discharge coefficient of 1.0 (1.0 DECLS).

Based upon these evaluations, the licensee concluded that for cosine power shapes, LHGR limits should be calculated using the boundary conditions for a 0.8 DECLG; for non-cosine power shapes LHGR limits should be calculated using the boundary conditions for a 1.0 DECLS.

Having determined the limiting break size for non-cosine power shapes, the licensee then assessed the effect of using a xenon induced top-skewed power shape as opposed to the nominal power shape. The results of that study, which assumed a LHGR of 9.4 kW/ft, showed that the nominal power shape obtained a peak cladding temperature of 1645°F, while the top-skewed power shape exceeded 2200°F. Thus, the licensee concluded that worst-case burnup-dependent xenon transient induced power shapes should be used in determining LHGR limits as a function of burnup.

The staff has evaluated the licensee's conclusions from the axial power shape sensitivity studies. We note that different approved evaluation models were utilized in examining the effect of axial power shape on the limiting break. As a result, we are unable to determine whether the change in the limiting break is the result of the axial power shape effect or the result of the different evaluation models used. Therefore, we required that LHGR limits based upon chopped cosine axial power shapes be calculated using the boundary conditions for a 0.8 DECLG calculated with a cold leg ΔP penalty of 0.8 psid. For non-cosine power shapes, LHGR limits must be calculated using the boundary conditions for a 1.0 DECLS calculated with a cold leg ΔP penalty of 0.15 psid. This requirement ensures that the LHGR limits are determined consistent with the power shape and evaluation model used in defining the limiting break.

The licensee's evaluation clearly showed that xenon transient induced top-skewed power shapes result in conservative assessments of the peak cladding temperature. Therefore, we find that the use of worst-case burnup-dependent xenon-transient induced power shapes in determining LHGR limits complies with the requirements of Section I.A of Appendix K to 10 CFR Part 50.

2.2.4 Burnup Sensitivity Analyses

Figure 3.2-1 of the Yankee Technical Specifications define allowable peak rod LHGR limits, as a function of burnup, for both the fresh (reload) fuel and the exposed (recycled) fuel. These limits have been developed to assure conformance to 10 CFR 50.46. For Cycle XVIII, the fresh fuel consists of forty assemblies manufactured by Combustion Engineering; the exposed fuel consists of thirty-six assemblies from Core XVII fabricated by Exxon Nuclear Corporation.

The licensee performed a series of LOCA calculations, for both the fresh and exposed fuel, to determine the LHGR limits as a function of burnup. The results of the evaluation are noted on Table 1. As the Table illustrates, for burnups of 1 GWd/MTU and less, the licensee utilized the chopped cosine power shape. The licensee stated that the worst case xenon transient induced power shape at these burnups is closely approximated by the chopped cosine power shape. Above 1 GWd/MTU, the licensee utilized the worst case xenon transient induced power shape (listed as "Xenon" on Table 1).

In all cases, peak cladding temperature was less than the 2200°F criteria of 10 CFR 50.46. Local cladding oxidation was calculated to be less than 10% of cladding thickness, thereby satisfying the 17% criteria of 10 CFR 50.46. Core wide metal water reaction was less than 1%.

We reviewed the licensee's calculations. Based upon the information provided in reference 6, we agree with the licensee's conclusion that a chopped axial cosine power shape closely approximates the worst case xenon transient induced power shape. Consistent with the licensee's axial power shape studies, the licensee has utilized the worst case xenon power shape for the other burnups. Also, as illustrated on Table 1, the licensee utilized the appropriate evaluation model (ΔP penalty) and limiting break size for the power shape analyzed. Thus, we find that the Technical Specification LHGR limits assure that Core XVIII operation of Yankee satisfies the requirements of 10 CFR 50.46.

3.0 SMALL BREAK LOCA ANALYSIS

3.1 Axial Power Shape Studies

The most recent small break LOCA analysis for Yankee was performed for Core XIII and is documented in reference 7. That analysis was performed using a chopped cosine axial power shape. To address the issue of compliance with Section I.A of Appendix K, the licensee provided additional calculations in reference 6. Three calculations were performed to assess the impact of top skewed axial power shapes on the small break LOCA. The specific cases analyzed for Core XVIII were the 4 GWd/MTU exposure xenon transient induced power shape, for both the fresh and exposed fuel, and the 14 GWd/MTU exposure xenon transient power shape for the fresh fuel.

Using the boundary conditions from the Core XIII blowdown analysis for the 4 inch break, which is the limiting small break for Yankee, the licensee performed heatup calculations, using the TOODEE2 code, for the cases described above. The licensee concluded that, since the cosine power shape has more integral power above the core mid-plane than the xenon transient power shapes, use of the Core XIII boundary conditions would result in earlier core uncovery and thereby conservative results.

The results of the licensee's calculations are given on Table 2. As can be seen from the table, all the cases analyzed resulted in peak cladding temperatures of 1700°F or less. Also shown on the table is the corresponding large break LOCA calculations for the same cases. These results confirm that the small break LOCA is still less limiting than the large break LOCA even when xenon transient induced top-skewed power shapes are considered.

Based upon our review of the licensee's calculations, we have concluded that the additional small break LOCA calculations demonstrate compliance with Section I.A of Appendix K. In addition, we find that the small break LOCA calculations demonstrate compliance with 10 CFR 50.46.

3.2 SIAS Low Pressure Setpoint Decrease

The licensee evaluated the effect of lowering the low pressure SIAS on the small break analysis. Like the large break analysis, discussed in Section 2.2.2, the licensee stated that the ECCS pump start time would be unaffected because it is based upon the emergency diesel start time upon loss of offsite power at time zero.

Based upon the licensee's statement, we conclude that the proposed Technical Specification change to lower the SIAS setpoint would not affect the small break analysis and is therefore acceptable.

3.3 Core Inlet Temperature Increase

The licensee evaluated the effect of increasing the maximum allowable core inlet temperature for Core XVIII by examining the Core XIII small break analysis of reference 7. For the limiting small break, the licensee estimated that the saturation pressure corresponding to 524°F would have been reached at 79.5 seconds. In the Core XIII calculations, the saturation pressure corresponding to 519°F was reached at 95.5 seconds. Thus, the increased core inlet temperature would result in saturation conditions at the core inlet occurring approximately 16 seconds earlier.

In addition, the licensee examined the effect of the increased core inlet temperature on the leak flow rate and energy removal rate. The licensee calculated that the leak flow rate would increase by ~1.7% and the energy removal rate would increase by ~1.2%. Thus, the licensee concluded that the system depressurization rate would not be significantly affected.

To estimate the impact of the earlier system saturation on the LOCA calculations, the licensee repeated the TOODEE2 calculation for the 4 GWd/MTU case for fresh fuel. This calculation was performed assuming the start of core uncovery 16 seconds earlier and increasing the duration of core uncovery by 16 seconds. This calculation resulted in a peak cladding temperature of 1882°F. Thus, the licensee concluded that the criteria of 10 CFR 50.46 would be satisfied with a maximum core inlet temperature of 520°F.

We have evaluated the licensee's assessment. Using the system depressurization rate calculated for the limiting break, we estimate that the higher system saturation pressure, 841 psia versus 805 psia, could possibly delay accumulator injection by 12 seconds. Thus, we conclude that licensee's use of an additional 16 seconds of core uncovery is conservative. We therefore conclude that the small break calculations demonstrate that Yankee satisfies the criteria of 10 CFR 50.46 with the proposed Technical Specification change to increase the maximum core inlet temperature to 520°F.

4.0 FUEL THERMAL AND MECHANICAL DESIGNS

The forty fresh assemblies are manufactured by Combustion Engineering (CE). The mechanical design for the CE fuel is similar to that of the current vendor, Exxon, except for some minor aspects (e.g., shoulder gap, spacer grid height, hold-down springs, etc). The licensee pointed out that the intent of the larger shoulder gap in the CE fuel is for extended burnup operation.

The fuel thermal analyses were performed using the approved GAPEXX code. Basically, the same methodology was used for calculating Core XVIII as was used for previous reloads. The results showed that for both types of fuel, Exxon and CE, the rod pressure does not exceed the system pressure, cladding collapse does not occur, and the BOL conditions yield the maximum fuel temperatures. Other thermal and mechanical analyses of Exxon and CE remain bounding for Core XVIII.

Thus, we conclude that the fuel thermal and mechanical designs are acceptable for Cycle XVIII.

5.0 NUCLEAR DESIGN

Pertinent nuclear design characteristics for Core XVIII are similar to those for core XVII. Radial power distributions for the unrodded core at hot full power conditions show that the maximum unrodded radial peak F_{xy} is 1.621 at 500 MWd/MTU, 1.549 at 8000 MWd/MTU and 1.463 at 14,000 MWd/MTU. The radial power distribution at 500 MWd/MTU with control rod Group C fully inserted has a peak F_{xy} of 1.794. The moderator and fuel coefficients are similar to those for Core XVII. The moderator coefficient for Core XVIII at BOL is less negative than the comparable Core XVII value because of a larger boron concentration.

Group C is used as the control rod group for Core XVIII as it was for Cores XIV through XVII. A comparison of control rod worths and shutdown requirements for Core XVII and Core XVIII was performed. The total control rod worth for Core XVIII is higher than that for Core XVII, and the excess shutdown margin is also higher. The control rod insertion limit curve for use during Core XVIII is unchanged from Core XVII.

The core depletion calculations were done using the PDQ/HARMONY model which has been used since Core XIII. The SIMULATE program was used for the calculation of reactivity parameters. These codes have been approved for Yankee.

A new axial shape LHGR curve was selected for the LOCA analysis; the new top-skewed curve is given in Figure 9-1 of YAEC-1496. The licensee demonstrated in the LOCA analysis for Cycle XVIII that the peak clad temperature calculated with this new curve bound both those calculated with the nominal and bottom-peaked curves which were used in the previous reload analyses. We find this acceptable. In addition, because of this new curve, the licensee proposed the removal of the F_I factor, which was intended to account for the power shift to the bottom of the core due to control rod insertion in full power operation. Because the F_I factor was covered by the new bounding curve, we conclude that the removal of F_I factor is acceptable.

We thus conclude that the nuclear design is acceptable for Core XVIII.

6.0 THERMAL-HYDRAULIC DESIGN

The thermal-hydraulic analyses of Core XVIII have been performed using basically the same methodology as the previous seven reloads (Core XI through Core XVII). The data presented show Core XVIII has significant margin to DNB, coolant quality, and fuel centerline melt limits. The design DNBR for Core XVIII is slightly lower than the reference analysis DNBR, 2.93 versus 3.07 at full power 4-loop operation. The difference is due primarily to the slight variation in hydraulic resistance between the CE and Exxon fuels. No changes were required to the safety limit curves for Core XVIII because these curves were developed in Cycle 15 based on conservatively bounding analysis.

The effect of rod bow has been considered for Core XVIII. A 34% DNBR credit is needed to offset the full closure rod bow penalty for Exxon fuel. A generic credit of 13.2% DNBR was accepted by the NRR staff (D. Crutchfield letter to J. A. Kay, dated July 22, 1981). The remaining 20.8% requirement for rod bow is offset by the 27.8% margin to the DNBR of 1.3, which is a result of the calculation of a minimum DNBR in excess of 1.8 for the most limiting anticipated transient (1 out of 4 pumps loss of flow). For CE fuel, the licensee, using the approved method, demonstrated that no penalty is required for Core XVIII.

We thus conclude that the thermal-hydraulic design is acceptable for Core XVIII.

7.0 ACCIDENTS AND TRANSIENTS

7.1 Introduction

The postulated accidents and transients were each considered by the licensee and compared with the most recent appropriate analysis. For most of the transients and accidents, the reference analysis was presented in the FSAR. For the majority of the accidents and transients we have determined that the reference analysis and bounding conditions in the FSAR are still applicable to the reload cycle. Thus we discuss only those analyses which deviate from the reference cycle.

7.2 Control Rod Withdrawal Incident

For Core XVIII, the assumed conditions in the reference cycle remain bounding. The design DNBR, however, is marginally lower for Core XVIII than for the reference analysis. The reference analysis showed that the minimum DNBR for this event was greater than 2.0, which is significantly above the 1.3 DNBR safety limit. However, taking into account the slightly lower design DNBR, the consequences of this event are still within design limits for Core XVIII. We find this acceptable.

7.3 Loss-of-Coolant Flow Incident

The moderator temperature coefficient for the reload core is more negative than for the reference cycle, and the minimum scram rod worth for the reload core is greater than the reference analyses. Thus, with the exception of the steady-state thermal margin, Core XVIII is bounded by the reference cycle.

For steady-state design conditions, the DNBR for the reload core is slightly less than the reference analysis. The total amount of pin failures predicted for a complete loss-of-coolant flow, although highly unlikely, remains below 1.15% as in the FSAR. Thus the analysis is acceptable.

The next category of limiting conditions for this event is the 1 out of 4 pumps loss of flow. The licensee showed a large DNBR margin available for this category, and thus predicted no fuel failures.

Therefore, we conclude that the loss-of-coolant flow analysis is acceptable for Cycle XVIII.

7.4 Control Rod Ejection Accident

The control rod ejection accident was conservatively re-analyzed for zero and full power conditions due to a large post-ejection peaking at BOL. The results showed that for both cases the fuel enthalpy was below 200 cal/gm, which meets the SRP limit of 280 cal/gm. Therefore, the fuel is assumed to maintain its coolable geometry. Since the applicable criteria are met, we find the analyses to be acceptable.

7.5 Steam Line Break Accident

Because the moderator reactivity feedback parameters and control rod worths were found to be more limiting for Core XVIII than for the reference cycle, a re-analysis of the main steam line break was performed. The analysis included a lower safety injection actuation setpoint of 1650 psig than was assumed for the reference analysis which used 1700 psig. The results show that there would be no return to power following the steam line break, and thus DNB and cladding damage are precluded. We considered this analysis acceptable.

9.0 CONCLUSION

Based upon the foregoing we have concluded that:

- The axial power shapes studies performed to generate the LHGR limits for Yankee satisfies the requirements of Section I.A of Appendix K to 10 CFR Part 50.

- The proposed Technical Specification to decrease the low pressure SIAS to 1650 psig does not impact the Yankee LOCA analysis. Therefore, the change is acceptable.

- The effect of increasing the maximum core inlet temperature to 520°F has been assessed in the Yankee LOCA calculations and found to be acceptable.

- The evaluations performed demonstrates that Yankee complies with the requirements of 10 CFR 50.46.

- The Core XVIII mechanical and thermal design has been reviewed and found acceptable.
- The Core XVIII Nuclear design has been reviewed and found acceptable.
- The Core XVIII Thermal-Hydraulic Design has been reviewed and found acceptable.

References

1. Letter, L. H. Heider (YAEC) to NRC, Subject: Core XVIII Refueling - Cycle Dependent Parameters, August 30, 1985.

2. Letter, G. Papanic, Jr. (YAEC) to J. A. Zwolinski (NRC), Subject: LOCA Injection ΔP Penalty, August 16, 1985.

3. Letter, G. Papanic, Jr. (YAEC) to J. A. Zwolinski (NRC), Subject: LOCA Injection ΔP Penalty, September 16, 1985.

4. Letter, J. A. Zwolinski (NRC) to G. Papanic, Jr. (YAEC) Subject: Revision To Yankee Atomic's ECCS Evaluation Model, November 27, 1985.

5. Letter, John A. Zwolinski (NRC) to James A. Kay (YAEC), Subject: Confirmation of ECCS Codes, May 22, 1985.

6. Letter, J. Hazeltine (YAEC) to J. A. Zwolinski (NRC), Subject: Additional Information for Core XVIII Reload Analysis, November 21, 1985.

7. Letter, W. P. Johnson (YAEC) to NRC, Subject: Auditional Yankee Rowe Core XIII Small Break LOCA Analysis, September 21, 1977.

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TABLE 1

YANKEE BURNUP SENSITIVITY RESULTS FOR CORE XVIII

Core Average Burnup GWd/MTU	Fuel Type	Power Shape	Evaluation Model ΔP Penalty, psid	Break Size	LHGR kW/ft	PCT °F
0.00	Fresh	Cosine	0.8	0.8DECLG	10.20	1994
0.25	Fresh	Cosine	0.8	0.8DECLG	11.25	2145
1.00	Fresh	Cosine	0.8	0.8DECLG	11.80	2157
4.00	Fresh	Xenon	0.15	1.0DECLS	11.00	1971
10.00	Fresh	Xenon	0.15	1.0DECLS	9.60	1973
14.00	Fresh	Xenon	0.15	1.0DECLS	9.40	2146
0.00	Exposed	Cosine	0.8	0.8DECLG	11.45	2160
4.00	Exposed	Xenon	0.15	1.0DECLS	10.50	1924
10.00	Exposed	Xenon	0.15	1.0DECLS	9.30	2148
14.00	Exposed	Xenon	0.15	1.0DECLS	9.10	2093
17.50	Exposed	Xenon	0.15	1.0DECLS	8.00	1565

TABLE 2

YANKEE SMALL BREAK ANALYSIS FOR CORE XVIII

Core Average Burnup GWd/MTU	Fuel Type	LHGR kW/ft	PCT °F	Large Break PCT °F
4	Fresh	11.0	1700	1971
14	Fresh	9.4	1520	2146
4	Exposed	10.5	1645	1924