Attachment

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
TEXAS UTILITIES ELECTRIC COMPANY, et al.	)	Docket Nos. 50-445 and 50-446
	)	
(Comanche Peak Steam Electric Station, Units 1 and 2)	)	(Application for Operating Licenses)

AFFADAVIT OF R.D. WHEATON, J.C. FINNERAN, AND R.C. IOTTI IN REPLY TO CASE'S PARTIAL ANSWER TO APPLICANTS' MOTION FOR SUMMARY DISPOSITION REGARDING SAFETY FACTORS

We, Robert C. Iotti, John C. Finneran and Randall D. Wheaton, being first duly sworn hereby depose and state as follows:

(Finneran). I am the Pipe support Engineer for the Pipe Support Engineering Group at Comanche Peak Steam Electric Station ("CPSES"). In this position, I oversee the design work of all pipe support design organizations for Comanche Peak. I have previously provided testimony in this proceeding. A statement of my professional and educational qualifications was received into evidence as Applicants' Exhibit 142B.

(Iotti). I am employed by Ebasco Services, Inc. as Vice President of Advanced Technology. In this position I am responsible for directing analytical and sometimes design work in diverse technical areas, including analysis of the response of structures, systems, and components to various normal and abnormal conditions. I have been engaged by TUECO to coordinate and oversee the technical activities performed to respond to the Board's Memorandum and Order of December 28, 1983. A statement of my educational and professional qualifications is attached to Applicants' letter of May 16, 1984, to the Licensing Board.

(Wheatón). I am employed by the IMPELL Corporation as the Staff Consultant for the Company's Advanced Engineering Division. In this position I am responsible for the technical direction of all seismic related work and research and development activities in the area of earthquake engineering. I had been asked by TUGCO to evalute the margins of safety which are inherent in the design of the Comanche Peak Steam Electric Station's structures, systems and components and in particular piping and piping support systems and components. In response I had assisted in the preparation of an affadavit attached to Applicants' Motion for Summary Judgment Regarding Safety Factors (May 20, 1984). A statement of my educational and professional qualifications was attached to that affadavit.

In our response to CASE's allegations concerning piping design issues at CPSES, we documented some of the safety margins that are known to exist in those designs. Whereas other affidavits have provided a detailed discussion of each specific item, the documentation of safety margins was an attempt to place the entire design process in proper perspective. Even CASE must recognize that there is only one real question at hand, and that is whether or not the design practices used at CPSES are adequate to ensure the safety of the piping systems. The quantification of design margins which we provided clearly answers that question in the affirmative. With design margins of approximately 40, CASE's concerns, even if they were given full credibility, remain insignificant. (Of course, this does mean to imply that Applicants should not or do not address legitimate concerns or comply with Commission regulations.)

It is important for the Board to note that CASE has not challenged our documentation of margins. Of the 13 major sources of conservatism that we have presented, and these are only the major items that have plant-wide impact, CASE has not managed to find fault with a single one. The Board can be reasonably sure, therefore, that such margins do exist. Such a conclusion is reinforced by every detailed study which has examined the piping design question and is proven beyond any reasonable doubt by the observed performance of piping systems during actual severe load conditions.

Rather than challenge these well-documented facts, CASE is now attempting to convince the Board, almost unbelievably, that the issue of safety factors is irrelevant to the safety of the plant; that it is somehow just a "deliberate attempt to mislead the Board" (CASE affidavit at 1). Their rationale for this position ranges from a factually incorrect discussion of load and capacity factors to a totally inappropriate reference to probabilistic risk assessments. It appears that CASE is simply throwing up random arguments in the hope that something will strike a responsive chord. While these arguments have little or no bearing on the issue at hand, we are of course forced to respond to them. The remainder of this affidavit, therefore, briefly addresses each of the points raised by CASE.

1. CASE first claims that our documentation of safety margins is an "apples" and "oranges" comparison (Id. at 1 and 6). They state (Id. at 3) that, "...the factors listed above (Applicant's documented safety factors) are not applicable to the design of piping supports at Commanche Peak, since they are related to Seismic B load factors and not capacity factors as required in the

working stress design, ..." They also claim (Id. at 5) that, "Applicants are not discussing factors of safety for design--they are actually discussing factors of safety for loads." These statements by CASE are factually incorrect on all counts. First, our documentation of safety margins dealt with both loads and capacities - and we clearly differentiated between the two. CASE even cites one paragraph from our affidavit (Id. at 6) where the distinction is pointed out explicitly. Second, the safety margins that we presented are completely unrelated to the "load factors" and "capacity factors" that are built into the various code equations. The code load factors, which are always greater than 1.0, and the capacity factors, which are always less than 1.0, represent an additional margin of safety which we did not take credit for in our documentation of margins. We deliberately omitted these factors because we were documenting the extent to which the actual CPSES designs exceeded the code requirements. Applicants have used all code-specified load and capacity factors exactly as the code intended.

Third, CASE's distinction between "factors of safety for design" and "factors of safety for loads" displays a complete lack of understanding of even the most basic engineering principles. The factor of safety in any design is nothing more nor less than the capacity divided by the load. Any conservatism added to the determination of either the load or the capacity translates into an identical conservatism--or factor of safety-- in the final design.

On the same topic, CASE also states (Id. at 5): "If the Applicants are so confident that they have a factor of safety equal to or greater than 46, why don't they decrease their load by 46 times and move on?/1/ Then instead of using a load factor of 1.7, they could have used a load factor of 1 + 1/46 = 1.02 ... Utilizing the Applicant's philosophy and realizing a load factor of 1.02, what the Applicants are in essence saying is that they do not need to consider seismic or dynamic events because there is only a 2% increase in load due to seismic or dynamic events."

Again, CASE is factually incorrect. The load factor (1.7 in CASE's example) is a multiplier that is applied to earthquake loads in certain code equations. It remains constant regardless of how the loads were actually derived. What Applicants have in fact shown is that the earthquake loads for CPSES have been overestimated by a factor of approximately 15.5. (The factor of 46 - corrected to 40 - erroneously cited by CASE includes the additional factors of safety that are associated with underestimating structural capacity). If Applicants chose to conduct a complete rigorous analysis, the excessive margin of 15.5 could be eliminated and all seismic loads would then be reduced by that same factor. The code-specified load factor of 1.7 would still be used (on the reduced load) and Applicants would still be in full

/1/ The total margin of safety documented in Applicants' Affadavit was a factor of 40 rather than 46. A Correction Sheet was sent to all parties on June 2, 1984. Whenever we quote from CASE's Affadavit and the value of 46 appears, the Board should note that the actual number should be 40.

compliance with all applicable codes and regulations. Again, however, the point that Applicants are making is that they are not simply in compliance with the code, they far exceed anything that is actually required by the code. The manipulations that CASE is performing with the load factor are totally incorrect and have no engineering basis.

CASE's "analysis" of how seismic loads only lead to a 2% increase in the total load is equally incorrect. Based upon a review of the stress analysis problems for CPSES, it has been stated that the seismic load is typically the single dominant load in the entire design. Given this fact, it is then clear that sizing the piping systems to carry a severely overestimated seismic load -- as Applicants have done -- is building in a safety factor to resist other loads as well. Even in those cases where the seismic loads are not dominant, there is no basis for CASE's statements. In the first place, most of the issues raised by CASE are irrelevant for non-seismic loads. More importantly, however, we have also documented corresponding safety margins for non-seismic as well as seismic loads. While these margins may not be as overwhelming as they are for the seismic case, there is less uncertainty in non-seismic loads and, hence, less need for large reserve margins. In any case, it should be clear to the Board that Applicants have never stated that there is only a "... 2% increase in load due to seismic or dynamic events." They have stated just the oppossite -- that seismic loads are the major loads on the piping system and they have a more than adequate design to resist these loads.

2. CASE further attempts to downplay the significance of the actual safety margins at CPSES by claiming (Id. at 1) that "...their (Applicants') statements give the erroneous impression that it doesn't really matter if things are wrong here and there, since they supposedly have this large margin of safety on the order of 46 (corrected to 40)." Even though CASE trys to paint the situation in the worst possible light, for once they are very nearly correct. A factor of safety of 40 would, in fact, compensate for the possibility of a great number of mistakes--far more than are claimed in all of CASE's allegations combined. That, however, is not the point. As we discussed in our original affidavit, all designs necessarily include some approximations. Every experienced engineer is aware of this and knows that a completely rigorous analysis in all areas is far beyond our present capabilities--on any structure. An experienced engineer also knows that he can still build safe structures by simply allowing for the approximate techniques he has to use. That is in fact the basis for all structural engineering, including that used on CPSES. The codes also recognize these simple facts and that is the basis for the "load factors" and "capacity factors" that CASE evidently misunderstands.

Many engineers will attempt to compensate for any approximation by introducing an additional margin of conservatism over and above that already contained in the codes. But these additional margins supplied by the engineer are not random; they always work in one direction and accumulate--compound, in fact--through each step of the design. If there are a large number of steps, the compounding conservatism can quickly assume major proportions. For the case at hand--CPSES--we have documented how the introduction of a systematic conservative bias in each major step of the design has resulted in an extraordinary total safety margin that is at least a factor of 40. With margins already in the range of 40 or more, it is obvious that the structural adequacy of the piping systems is not the controlling factor in the overall safety of the plant. Further increasing those margins, would not provide any measureable benefit but would have an enormous impact on costs.

As an alternative to providing additional margin, Applicants could use a different analytical technique in each of the areas questioned by CASE. But this, too, would accomplish nothing; it is merely trading one approximate technique for another. The reanalysis would undoubtedly result in a marginal redistribution of computed support loads but this would be a random redistribution and the new results would be no more accurate than the old.

The techniques that engineers have devised to address structural problems are designed not to produce "exact" results--because there are none--but to place the answers within manageable bounds. The codes then provide safety factors to allow for the approximate nature of the results. Applicants have also introduced additional safety factors that are many times greater than those required by the codes. To now go back and attempt a more detailed analysis in the areas questioned by CASE would have about as much impact on the safety and reliability of the design as using a different pencil.

3. CASE claims (Id. at 2) that the supports at CPSES are unique and that Applicant's witnesses are not qualified to comment on them. Also, because of this uniqueness, all of the experience gained by engineers from the past history of other structures is not valid. Every design is "unique" but the differences between the CPSES piping systems and those at other plants are on the micro-level compared to those qualities that actually govern structural performance. In terms of the safety of the plant, there are only a few items of serious concern, such as the static strength of the members, the general frequency characteristics of the systems, the ability to deform inelastically and absorb energy, and the ability to redistribute loads and stresses throughout the system. In these areas that count, the CPSES piping sytems are virtually undistinguishable from other plants. And past history tells us that structural systems of this type perform very well indeed, even for loads that far exceed their original design bases.

CASE also claims (Id. at 2): "When one neglects the normal operating loads and stresses, one cannot be assured that the structural system will be operating in a predictable manner for a dynamic event." This statement is meaningless. Not only have Applicants considered all "normal operating" loads but also the far more severe loads associated with "upset", "faulted", and "emergency" conditions--and all in myriad combinations.

4. With regard to CASE's discussion of TMI and the Kansas City walkway collapse (Id. at 6), since CASE has not bothered to explain in what fashion these are relevant to the CPSES piping systems, a response is not warranted.

5. Starting on page 7 of their affidavit and continuing through page 15, CASE proceeds to inform the Board of "...what Applicants are not telling the Board is stated in those documents" (i.e., Applicant's references). For example, CASE points out that one reference reminds the engineer that "...rigorous nonlinear dynamic analysis methods are valuable tools in seismic analysis and design when combined with engineering judgement, careful detailing, and quality construction workmanship..." Since Applicants are not using nonlinear dynamic analysis methods, rigorous or otherwise, there was no reason to mention these points.

CASE also cites (Id. at 7 and 8) from one of Applicant's references a rather lengthy paragraph dealing with quality control and random errors. Since, as CASE so carefully points out, I (R.D. Wheaton) helped prepare the reference, I can testify that CASE has missed the point. The entire document was a major attempt (over 3 years in preparation) to examine the safety margins in nuclear structures in relation to the uncertainty and approximations that are inherent in our current technologies. Within the context of that effort, the paragraph cited by CASE was noting that the possibility of random errors made it more difficult to accurately determine the true factor of safety in any design. It was also a general reminder that there is never a substitute for good quality engineering. Even allowing for random errors and less than perfect construction, however, the conclusion of that study was that the safety margins in the average nuclear structure (including piping systems) appear to have grown to unnecessary and even excessive proportions. The factor of safety at CPSES is even greater than at the average nuclear plant.

The next of the Applicant's references cited by CASE (Id. at 8 and 9) was prepared by the late Dr. Nathan M. Newmark--the most highly respected structural engineer of this era. It was Dr. Newmark who first suggested that the criteria used to design nuclear structures might be getting out of hand in the area of conservatism. The document cited by CASE was an attempt by Dr. Newmark to develop a more realistic set of criteria than those that are currently being used (as, for example, at CPSES). It was, as CASE pointed out, commissioned by the NRC and was subsequently used by the NRC to systematically reevaluate older nuclear power plants--those built before the current criteria were fully developed. It is still being used by the NRC in their evaluation of newer plants and in their continuing efforts to develop more rational design standards for nuclear structures. I respectfully suggest to the Board that if Dr. Newmark knew that he was being quoted by CASE as even hinting at the possible inadequacy of modern nuclear piping systems, he would roll over in his grave.

CASE next cites (Id. at 10 and 11) a number of references by Applicant, and Applicant's references, to the term "current nuclear engineering practice". The only point of all these citings seems to be an excuse for CASE to introduce an NRC/ACRS memorandum dealing with PRA studies (probabilistic risk assessments). CASE claims that the memo is an attack on the "untempered r[illegible] the nuclear industry" (Id. at 11) on PRA's. If the Board has read [illegible]y will have seen that i[illegible] y states that PRA studies are good [illegible] and not good for other[illegible]. I would not quibble with that [illegible] but I do have a difficult time seeing how it is relevant to the [illegible] piping systems. Applicants have not used a PRA study in the design of

CPSES. To date, the only way that PRA studies have been used in the nuclear industry is as a tool to evaluate the relative significance of different possible events--something the memo says that they are, indeed, good for.

CASE's next example of what "Applicants are not telling the Board" (Id. at 11), and "which Applicants have conveniently forgotten to inform the Board" (Id. at 12) has to do with the whole area of uncertainty in structural design. CASE again is wrong. In our original affidavit, we repeatedly, and very clearly, pointed out the many sources of uncertainty in the design and analysis of nuclear structures-- particularly as regards to seismic events which are the controlling load for CPSES piping systems. Virtually the entire affidavit, in fact, was a discussion of the uncertainties endemic to our current design practices and the steps taken to ensure safety in spite of them. As was very clearly pointed out, it is the continuous introduction of safety factors to compensate for uncertainty that ultimately results in the extraordinary final margins that we have documented in relation to the design of CPSES piping systems. CASE's entire discussion of uncertainties reflects a lack of understanding of basic engineering principles associated with this issue.

CASE does bring up one very important issue when they state (Id. at 14 and 15) that if the seismic margins are so significant, then the codes would have addressed them and Applicants would have utilized lower safety factors. Applicants could, in fact, have eliminated every source of conservatism identified in our Affidavit by employing alternate analytical techniques or by utilizing available test data. Applicants would still be in full compliance with all codes and regulations. The point that CASE does not understand is that the codes define approximate design methods and criteria that <u>may</u> be used. These code-specified approaches are acceptable not because they are accurate but because they are conservative. The codes always allow the engineer to use more rigorous methods on any project. As we pointed out in our affidavit, more rigorous methods are available but their use on projects the size of CPSES entails considerably more cost and effort. Applicants have chosen to live with significant conservatism in an attempt to increase design and construction efficiency.

6. On page 15 of their affidavit, CASE introduces another memo. This one supposedly shows that Applicants entire "premise" is not valid because of a 30% "overstress" in one bolt. To an unbiased observer, what this memo would actually show is the triviality of CASE's position. In the first place, a random "overstress" of 30% is truly insignificant in the face of the margins that have been documented for that same structure. Not only is that bolt <u>not</u> overstressed at all, but is still <u>understressed</u> by a factor of roughly 11. This is shown quite easily by using the specific design data for that bolt and the reserve margins which we included in our original affidavit: i.e., the load on the bolt is approximately 60% seismic and 40% non-seismic; the margin on the seismic load is at least 15.5; and the minimum static margin for the capacity of a bolt is a factor of 1.68. If we plug this data into the equation which supposedly showed a 30% "overstress," we have the following:

$$\left[\frac{.4(9740) + .6(9740)/15.5}{1.68(12110)}\right]^2 + \left[\frac{.4(6362) + .6(6362)/15}{1.68(7850)}\right]^2 = 0.09$$

In other words, the use of the correct data shows that the bolt is really only stressed to an almost negligible 9% of its capacity. The factor of safety is the inverse of this or a factor of 11. The Board should note that these results were obtained using the same data which has already been documented in our affidavit and which has not been challenged by CASE.

In the second place, as the memo clearly states, the stress evaluation was based upon a "worst case condition"; i.e., a crude analysis that neglects important factors. A worst case analysis that shows no more than a 30% overstress is a strong indication indeed that the structure is adequate. The memo indicates as much by pointing out that the portion of the load carried by another bolt in the same joint was completely neglected.

Lastly, but probably most importantly, a 30% "overstress" in a steel structure, even if it were a real overstress and not just a paper problem, is an insignificant event. Any excess loads would quickly be redistributed to adjacent members with no detrimental effects. This ability to redistribute loads, which even CASE must recognize is an inherent characteristic of steel structures, provides a tremendous reserve strength to resist any possibility of overload. The codes certainly recognize this ability and even allow the engineer to utilize it in design if he so chooses. Applicants have not done so. In fact, Applicants have not even claimed it in the documentation of safety factors because it is quite difficult to define the resulting margins in any generic sense. It is there nonetheless, and once again demonstrates the lack of any real merit in CASE's allegations.

7. CASE next introduces another memo (Id. at 15) dealing with the use of "refined response spectra". CASE claims (Id. at 16) that these spectra can not be used to evaluate "inelastic deamplification" at CPSES because they are not "elastic spectra"--they are "reduced" or inelastic spectra. CASE is again factually incorrect from every perspective. First, the refined response spectra at CPSES are the same elastic spectra that are used in the design of all important structures. They are in no way related to "reduced" or inelastic spectra as claimed by CASE. The refined spectra in fact would have to be reduced by at least a factor of 2 to 3 to correspond to the inelastic spectra which CASE is objecting to.

Second, the Applicants' reference that is being cited by CASE is actually stating that elastic rather than inelastic spectra should always be used for the <u>design</u> of secondary systems. This is exactly what Applicants have done in each and every instance. When it comes to evaluating the <u>margin</u> in a given design, however,the inelastic spectra is entirely appropriate, and it is in precisely this fashion, and only this fashion, that we have used it (Applicant's Affidavit Regarding Safety Factors at 33-35).

Third, even if there were some technical merit to CASE's claims, the Board should note that we have not even included the resulting margins, which are very large, in our documentation of safety factors for CPSES. If we did include this item (i.e., the inelastic behavior of the structure). The total margin would be in the range of 70 to 90 rather than the value of 40 which we quantified in our affidavit.

8. On pages 16 through 19 of their affidavit, CASE addresses our references dealing with the past behavior of structures during earthquakes. They first claim (Id. at 17) that it would be "unconservative" to compare the El Centro Steam Plant with Comanche Peak because of numerous dissimilarities between the two. Whether such a comparison would be conservative or unconservative is open to discussion but this is a moot point because Applicants have not, in fact, made such a comparison. What we have done is compare the design basis loads for the El Centro plant with the loads this plant actually experienced during an earthquake. This comparison demonstrated two major points:

a) The engineered structures safely withstood loads far in excess of their predicted capacity. This shows that we seriously underestimate the actual capacity of real structures.

b) An analysis of the El Centro piping systems using the same methods that are being used at CPSES predicted a gross overstressing of both the pipes and the pipe supports. This demonstrates that the analytical techniques used in the nuclear industry are indeed conservative and lead to a major overestimation of the loads on piping systems.

CASE points out that there was some damage at the El Centro plant. By any measure, this damage was trivial and was confined to non-seismically engineered components. It is quite reasonable to expect that had the entire plant been designed to resist seismic loads--particularly loads of the magnitude that actually occurred--then even this minimal damage would have been prevented. In this regard it is worth noting that the simple equivalent static design method that was used for the El Centro plant is intended solely to prevent a complete structural failure. Damage--even major damage--is considered acceptable as long as it does not lead to total collapse. As it turned out, even this simplified design philosophy led to a structural system that performed very well during a major earthquake.

CASE's comments on the observed performance of the Huachipato Steel Plant in Chile (Id. at 18) are confined to a simple listing of the damage which did occur. They make no attempt to evaluate the type of damage which occurred or to place it in a design versus performance perspective. Had they done so they would have noted that virtually all of the damage they cite was the result, not of "inadequate seismic considerations", but of no seismic considerations at all. In terms of the structural components that were actually designed to resist lateral loads, this case history is a remarkable demonstration of just how well engineered structures do perform during earthquakes. The Huachipato Steel Plant was designed using the most simplified techniques available and only nominal seismic loads. It was then subjected to an earthquake of major proportions (M = 7.5) occurring very close to the plant. All conventional design standards would have predicted very serious and extensive damage, if not total structural collapse. This did not occur. On the contrary, the damage was so minor that the plant was fully operational again in 6 days.

Both the El Centro Steam Plant and the Huachipato Steel Plant provide well documented benchmarks against which the CPSES design can be evaluated. The following points are noteworthy:

a) Both of these plants were designed using methods that are extremely crude compared to those used at CPSES.

b) Both of these plants were designed to resist seismic loads much smaller than those considered at CPSES.

c) Both of these plants are situated in high seismic zones and actually experienced earthquakes that are near the upper limits for those zones. Comanche Peak, on the other hand, is located in one of the most seismically inactive regions in the United States--a region where earthquakes of the type that affected the El Centro and Huachipato plants are simply not credible events.

In summary, experience shows us that structures designed using very simple methods and for quite small loads, have still performed very well during major earthquakes. The Comanche Peak piping systems, on the other hand, have been designed using much more sophisticated methods to resist large seismic loads--but will only experience small seismic events. Given these facts, it is not difficult to understand the basis for our statements that large seismic margins do exist for the CPSES piping systems. The "seismic test" that CASE claims the "Applicant can not and will not perform" (Id. at 20) has, in fact, been performed many times--under far more realistic and extreme conditions than could ever be duplicated on a shake table. The results consistently document just how well engineered structures perform during earthquakes--particularly ductile steel structures such as the CPSES piping systems. Our affidavit quantifying the actual margins at CPSES has attempted to explain to the Board at least part of the reason as to why this occurs. Whether or not we have succeeded with our explanation, both engineering theory and the observed behavior of structures demonstrates that there is no genuine issue regarding the safety of the CPSES piping systems.

SWORN TO BEFORE ME THIS FIRST DAY OF NOVEMBER, 1984:

[signature]

Randall D. Wheaton

GENERAL ACKNOWLEDGMENT

State of California
County of Contra Costa } ss.

On this the 1st day of November 1984, before me, Donna L. Grajek the undersigned Notary Public, personally appeared Randall D. Wheaton

☐ personally known to me
☒ proved to me on the basis of satisfactory evidence

to be the person(s) whose name(s) is subscribed to the within instrument, and acknowledged that he executed it.

OFFICIAL SEAL
DONNA L. GRAJEK
NOTARY PUBLIC - CALIFORNIA
CONTRA COSTA COUNTY
My Commission Expires May 10, 1985

WITNESS my hand and official seal.

[signature]
Notary's Signature

Robert C. Iotti

John C. Finneran, Jr.

STATE OF TEXAS
COUNTY OF SOMERVELL

Subscribed and sworn to before me this 1st day of November, 1984.

Bill G. Hodges
Notary Public
MY COMMISSION EXPIRES MARCH 28, 1988

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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	)	Docket Nos. 50-445 and 50-446
TEXAS UTILITIES ELECTRIC COMPANY, *et al*.	)	
	)	(Application for Operating Licenses)
(Comanche Peak Steam Electric Station, Units 1 and 2)	)	

CERTIFICATE OF SERVICE

I hereby certify that copies of "Applicants' Reply to CASE's Partial Answer to Applicants' Motion for Summary Disposition Regarding Safety Factors" in the above-captioned matter were served upon the following persons by deposit in the United States mail, first class, postage prepaid, this 2nd day of November, 1984.

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