November 1, 1984

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
METROPOLITAN EDISON COMPANY	)	Docket No. 50-289 SP
	)	(Restart-Management Remand)
(Three Mile Island Nuclear	)	
Station, Unit No. 1)	)	

TESTIMONY OF WILLIAM W. LOWE

My name is William W. Lowe. I am a founder and Chairman of the Board of the engineering and consulting firm of Pickard, Lowe and Garrick, Inc., as I was at the time of the TMI-2 accident. And I am now, as I was then, a consultant to the General Public Utilities Corporation concerning nuclear power matters.

The account which follows is about the containment pressure spike referred to in the mailgram from Mr. H. Dieckamp to Congressman Udall of 9 May 1979. I will describe my direct personal knowledge of how and when the spike was first recognized to be evidence of major core damage and how and when this view was verified.

I have been careful to reconstruct events as they were, not as they may now be perceived, and have consulted colleagues in the interest of accuracy. The clock times given for some events may be in error but not, I believe, by more than a few hours.

In judging when the significance of the containment pressure spike was first recognized, it is important to know when it was not. So I will start by summarizing my knowledge of prior events and will end by saying that this knowledge, based as it is on intimate personal involvement in the matters described by the mailgram, leads me to the clear conclusion that the statements in the mailgram are accurate concerning the spike.

At 0830 on 28 March 1979 our office in Washington was notified by GPU personnel of potential radioactive releases from TMI-2 and we were requested to provide weather data. At 0930 the request was repeated. We were asked because we have computers in Washington which can read, correlate, and double check weather data being measured by instruments on the weather tower at the TMI site. These computers can also compute radiation doses using such data. At 1025 we were informed that an accident had occurred and a general emergency declared. At 1140 Mr. Jack Thorpe, a senior manager for GPU, called and asked me to stand by to come to TMI-2. He was then Chairman of the TMI-2 General Office Review Board of which I was and am a member. At 1150 I called several of our engineers in from around the country so they would also be available. At 1620 I called Mr. Thorpe requesting status and learned that there had been a steam bubble in A and B loops of the primary system preventing operation of the reactor coolant pumps but the steam in one loop had been condensed and cooling was by feed and bleed.

He reported the plant thinks core cooling is recovered. There were more than ten, probably as many as twenty, phone calls between our Washington office and GPU during the day and evening and some of them were extensive. No mention was made of the pressure spike or hydrogen.

The next morning, the 29th of March, at 0830, Robert Arnold, then Vice President for Generation of GPU Service Corporation, called me regarding the formation of an Events Analysis and Recovery Planning Team. He asked me to be a member and to come to the TMI Observation Center by early afternoon. I called Bob Keaten at GPU about 0930 and recommended primary coolant be sampled and measured for the isotope silver-110 which, if present, would have implied damage to control rods. I arrived at the Observation Center about 1400. A briefing for several U.S. Senators was underway in which Mr. Herbein, Mr. Dieckamp and others were involved.

After this was over, the Analysis and Recovery Team members, comprised of senior technical people from GPU and myself, assembled at 1530 in the TMI-1 supervisors conference room and were divided into two groups: one for Events Analysis and one for Recovery Planning. I was assigned to the latter. There was considerable discussion of the division of work between the two groups and a briefing about plant status. A decision was made to debrief all operators coming on or off shift and record their accounts of what happened.

I believe we were told during the meeting, which started at 1530, and/or during a discussion with Mr. Kunder immediately thereafter, that the waste gas decay tanks were near their relief pressure. A large part of the gas in them would normally be hydrogen. No one mentioned or implied, however, that there had been hydrogen produced by a reaction between zircalloy fuel cladding and water or that there had been an ignition or explosion of hydrogen in containment or anywhere else. Knowledge of the accident was no where near that complete.

The meeting began to break between 1700 and 1800 to get food and so that each group could work separately. At this point Mr. George Kunder took me aside for a short but intensive explanation of what he perceived to be the urgent needs of the plant. After about ten minutes of it, several of us decided we should go to the control room forthwith and get first-hand information. Consequently, two GPU engineering managers and I suited up, and did so.

In the control room we talked with some operators and engineers and observed what was going on. There seemed to be unresolved problems relating to plant stabilization and damage control. The operators were having trouble holding the pressurizer level steady.

After half an hour or so, we left the control room and went to eat with several others. We discussed what we knew of plant status and accident sequence and how to proceed with recovery planning. We tried to contact Gary Broughton to get more information about accident sequence. Earlier he had shown some of us a preliminary analysis of the first minutes of the primary system pressure and temperature transient. When we found him, he confirmed the system had reached saturated conditions within the first few minutes after the reactor trip.

After dinner, the Recovery Planning group to which I had been assigned met in a hotel room to discuss approaches to recovery planning. These discussions focused on how to identify equipment requiring repair and replacement and how to clean up liquid, gaseous and solid radioactive wastes. Several of us were uncomfortable during these discussions because we sensed we should go to the plant to get more information and to assess some of the problems operations was having. Consequently, the group went back to the TMI-1 supervisors conference room at the site.

Shortly after we had reassembled at TMI, I followed Mr. Herbein, the site leader, as he left the conference room and told him the basic problem was stabilization, not recovery, and that several senior people should be assigned forthwith to the control room to help with stabilization and damage control. Mr. Herbein immediately re-entered the conference room, reiterated this position, and asked for volunteers. Tom Crimmins, who at the time was Manager of Generation Engineering for Jersey Central Power and Light Company, and I volunteered, suited up and went to the control room at about 2200 hours.

Our first priority was to connect the two waste gas decay tanks back to the containment. These tanks contained radioactive gas and were near relief pressure. We assumed a primary constituent of the gas was hydrogen as it would be in normal operation and we planned carefully to avoid its ignition in situ or as it entered containment. I insisted there be a flame arrestor in the line of tubing which was to connect the tanks with the containment. We requested an investigation to find any potential ignition sources within twelve feet of the exit point. After the plan was outlined, execution was turned over to Ron Toole who had reviewed the pertinent drawings with us.

We then sought further information about plant status. We were told that the primary system was still "mushy," that is, it was hard to control pressurizer level. The operators were concerned about this problem but still had no explanation which made sense. They thought there might still be a steam bubble outside the pressurizer but none of the many temperature readings were high enough for that.

At about 2300 the operators lost control of pressurizer level and Joseph Logan, Unit 2 superintendent, who with several others was conferring with Crimmins and me in the supervisor's office at the back of the control room, left to take direct charge of the operating crew. I followed to observe. At that point, a young engineer assigned to collect data approached me and said, "Have you seen this?" He held out the containment building pressure recorder chart trace showing a pressure spike of 28 psig at 1350 hours on 28 March, the previous day. I concluded instantly without further discussion that the spike was caused by hydrogen ignition in the containment, that therefore the mushiness in the primary system had to be due to the presence of hydrogen gas loose in the primary system, that the hydrogen was from a zircalloy-water reaction and that we had to get the hydrogen out. The spike looked like those we used to calculate for hypothetical hydrogen ignition in containment except it came down faster. Containment pressure was subatmospheric which could be due to having used up oxygen by burning hydrogen. I asked the young engineer for another pressure reading and he pointed to the wide range trace at the bottom of the same chart. I asked for building temperature traces. They were confirmatory.

I asked for xerox copies and stepped back into the shift supervisor's office where Tom Crimmins was with several others and told him that there had been hydrogen ignition in containment, that there was a hydrogen bubble in the primary system, that we had to measure it and that we had a fighting chance to get it out because hydrogen "diffuses like a shot." The great sense of urgency to measure the size of the bubble derived not only from wanting to confirm or refute its presence but also to find out whether it was growing, to find out whether it was then large enough to interfere with reactor coolant pump operation on which core cooling then depended, and to estimate whether the core could be uncovered by bubble growth if depressurization occurred by failure of pressurizer heaters or a critical seal or valve. While the term bubble was used then, as it is now, we knew it could be several or many bubbles in a number of places.

One aspect of the events just described may need explanation at this point before resuming the account of what happened next. Sardonic doubt was once exhibited in my presence as to how the meaning of the spike could be rapidly apparent among the many things going on. I think the question of why I recognized it whereas others apparently hadn't deserves consideration, and the answer, I believe, is at least three-fold.

First, on the 29th, puzzles had been accumulating all evening. The primary system acted as though steam was in it outside the pressurizer but temperatures were too low. The waste gas tanks were full but we did not know why. Lots of radiation was loose in containment, but we did not know what the fuel damage was like. And we felt a great urgency to get answers. The visual image of the recorder trace resembled graphs of calculated hydrogen pressure spikes I had seen before and that image was the trigger which made all the then-known pieces of the puzzle fall in place. This kind of thinking is intuitive, not analytical in the pedestrian sense. But, I believe it is a well recognized psychological process.

The second factor is background. Although I am a licensed nuclear engineer, my degree is in chemical engineering and I worked in that field and chemistry for five years during which

I had personal experience with both the potential for and the actuality of fires and explosions. During the early years of nuclear reactor design we were especially sensitive to the possibility that metals such as aluminum, stainless steel and zircalloy used as fuel cladding could react with water at high temperatures to produce hydrogen and destroy the cladding. Later on, accident analyses such as those for TMI, included consideration of these reactions as well as hydrogen production in containment by radiolysis and by reaction of spray water with aluminum and zinc. Those familiar with these analyses knew the aluminum source was over-estimated and radiolysis was slow. Most operators and many engineers did not have this kind of background then and so probably were not as sensitive to the possible meaning of a pressure spike.

The third factor is stress. Although I am not an expert in this area, I know from experience that except for those who freeze, acute stress makes one especially alert to start with but dulls analytical and physical capabilities fast. Stress is especially high if one can't figure out what is going on. The operators and most others present upon my arrival in the control room had been under high stress for long periods. Some of them had not slept much, if at all, in about two days. We, on the other hand, while under high stress, were relatively fresh, better able to interpret the more obscure clues such as the spike.

Given these three factors, I do not find it surprising at all that the situation developed the way it did. I don't find it surprising in such a complex, confusing, unprecedented and on-going situation that it took a combination of circumstances and a fresh look to recognize the significance of what may at first have appeared to be a spurious instrument reading among hundreds of other readings and alarms and plant control problems. I say this because I have a recollection, imprecise as to time, that mention was made among many other things in my presence at some point on March 29 of a containment pressure recorder spike said to be a spurious indication: e.g., caused by a voltage anomaly in instrumentation. I recall being skeptical of that explanation. In all the discussions, however, no one had exhibited or implied in my presence any recognition of the significance of the containment pressure spike. Nor did I pause to reflect on my skepticism at the time and, indeed, until the graph of the spike was shown to me which prompted the reaction described above.

And this leads back to the story. I knew from personal experience that under high stress one tends to lock-on to a perception of reality which, even if the best available, may be wrong. I had been trained to recognize and handle such situations. So even though we felt great pressure to act, Tom Crimmins and I forced ourselves to take the time to review the facts and test the logic of the hypothesis about the spike and related matters. When the hypothesis held up, I called someone and asked for the best man available to help us. Shortly afterward at about 2330 Mr. Jim Moore, an experienced GPU engineer arrived.

The three of us sat in the shift supervisor's office trying to figure out how to measure bubble size. Finally, after what seemed a long time but probably was not, Jim Moore said, "Boyle's law ought to work" and I recall thinking, perhaps saying almost before he had finished, "And the pressurizer is the piston." Boyle's Law states that, other things being equal, the volume of a perfect gas is inversely proportional to absolute pressure. Although other things were not equal and hydrogen is not quite a perfect gas, it was obvious that the volume of a bubble, if there was one in the primary system, could be measured approximately by measuring the difference in system pressure caused by a given difference in pressurizer level. I asked Joe Logan, the TMI-2 Superintendent, to change level to get about a 100 psi pressure differential. Operations said they had some data like that from the previous day. I asked that it be "QA'd," that is, verified before we used it and then commandeered the open telephone line to Lynchburg from a B&W engineer and made two urgent, highest priority requests of Don Nitti and Jim Taylor whom I found at the other end:

First: What is the free volume under the head of the reactor pressure vessel down to the top of the nozzles?

Second: Make refined calculations of bubble size, using pressure, temperature and pressurizer liquid volume change information we would give them, taking account of gas solubility and anything else pertinent assuming the gas is hydrogen.

Jim Moore and I then made calculations of bubble size independently and got approximately the same answer. When we corrected each other we had a bubble size of 1568 cubic feet at 875 psia from data taken at 1245 on 29 March. My calculations are time marked 0235 on 30 March. Subsequent estimates from data taken about 0330 on 30 March gave a bubble volume of about 1100 cubic feet at 875 psia. We had not yet gotten proof of the interpretation of the pressure spike but the hypothesis had been greatly strengthened.

At about 0325 hours B&W called back to report the free volume in the reactor vessel down to the outlet nozzles was 1129 cubic feet. Even though the first bubble volume calculated of 1568 cubic feet was larger than this, and the second about equal, it was clear the core wasn't uncovered. Questions to Operations indicated amperage and vibration were normal for the one primary pump which was running. So there wasn't enough hydrogen to interfere with main pump operation at then current system pressure. But there was enough so that depressurization could uncover the core and defeat core cooling by methods then being used.

Shortly before 0400 after talking to B&W, I started to calculate the amount of zirconium cladding in the core which must have burned to produce enough hydrogen for global ignition in containment and for a hydrogen bubble of the size measured. I stopped before completion because of the press of urgent matters and since rough numbers and mental corrections indicated a large part or all the zirconium had burned. I didn't necessarily believe all of it had, but it was clear now that the core was very seriously damaged. That was what we needed to know at that time.

At about 0400 after discussions with Crimmins and Moore, I recommended to Joe Logan that he start venting the pressurizer to containment while holding the pressure at the then current level of about 970 psig with pressurizer sprays and heaters on as much as possible. I also asked that analyses of the hydrogen and oxygen content of the containment atmosphere be obtained as soon as possible. The venting was aimed at removing hydrogen from the primary system by steam stripping dissolved hydrogen from the hydrogen rich water brought to the pressurizer by the sprays on the assumption that the hydrogen in the bubble would "diffuse like a shot" and replace that stripped and so the bubble would gradually disappear. Venting from the pressurizer was started later on 30 March.

Containment atmosphere sampling done between 0518 and 0638 of 31 March showed residual hydrogen of 1.7% and oxygen of 16.3% by volume clearly supporting the hypothesis of a hydrogen ignition. The normal concentration of oxygen in air is about 21% and hydrogen is essentially absent. At 2338 of 1 April B&W reported by telephone that at 1550 that day the bubble in the primary system had disappeared according to volume calculations and noise measurements. This was confirmed by a graph sent to me and received at 0044 of 2 April. The disappearance of the bubble was consistent with the initial interpretation of the spike. As more information was accumulated over the next days and weeks, the initial interpretation was demonstrated without doubt to be correct.

I find it inconceivable that if anyone had known hydrogen was present in containment and had ignited, they would have concealed that knowledge from peers or managers and that the on-site technical support team would not have been told of it. No motive for concealment by those involved existed since too much was at stake including, perhaps, their lives.

Also, I find it inconceivable on other grounds that the real significance of the pressure spike was deliberately concealed by an exercise of duplicity or dishonesty. I know many of the people involved and have for years. They simply would not have done such a thing. And when I say that I include Mr. Kuhns, Mr. Dieckamp, Mr. Arnold and all of those managers and engineers with whom I worked during the accident.

In the course of working with Mr. Dieckamp during the accident, my high regard for his honesty, managerial ability and patience, which has certainly been tested under very difficult circumstances during the past five years, was reconfirmed. I might add that Mr. Dieckamp gave a great deal of personal attention to what was going on during the TMI-2 accident. He, for example, called me directly several times near midnight of Friday, 30 March when he was concerned, as we all were, about the potential for another buildup of hydrogen concentration in the containment due to venting the primary system and due to the slow radiolytic decomposition of water in the bottom of the containment building.

To recapitulate, no recognition of or even speculation about the significance of the pressure spike was expressed or implied in all of the extensive and intensive communications I heard or was party to from early morning of 28 March until the spike's significance was recognized at about 2300 on 29 March as I have described. These communications were with both senior and junior engineers, operators and managers, probably more than 50 in all. Nor did I hear about any such prior recognition from the hundreds of people I dealt with subsequently while on duty at TMI for nearly a month. Furthermore, the people I know and dealt with would not have deliberately concealed such knowledge. And I state that judgement with emphasis and without qualification.