

SET PHASERS ON STUN



And Other True Tales of Design, Technology, and Human Error

SECOND EDITION

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BUSINESS IN BHOPAL

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Chairman Warren M. Anderson, Union Carbide Corporation, ducked his head as he emerged through the open doorway of the jet plane and stepped purposefully down the slippery metal stairs, one hand clutching the rail. It had been a very long day, and he was determined not to slip in front of the spectators and TV cameras. The last step down was the one onto the solid and seemingly reassuring gray asphalt of the airport tarmac. A slight breeze drifted by and his attention shifted involuntarily to the horrid stench in the air. It was a putrid mixture of jet fumes, industrial effluent, animal waste, and humanity; the smell of a living nightmare. Yet, there he was, right in the middle of it all.

The flights had taken him from the solace of wintertime Connecticut to this dirty and troubled city in central India, halfway around the globe. Images were more important now than ever before, but somehow the scene was not unfolding as planned. He flew here to demonstrate Carbide's concern, but it was not coming across well. There stood the wealthy American executive with his entourage in tow, intent on conveying his empathy to the residents of this sprawling third-world city, most of whom lived in abject poverty. His tailored clothes, gray hair, and heavy black glasses were just the finishing touches to the picture. He could not have looked more out of place, and he was not fully prepared to face what were to be perhaps the worst moments of his 63 years of life.

Everywhere, on the other side of the wire fence surrounding the field and through the windows of the buildings, were the small dark faces of people, hundreds and hundreds of people. They all looked alike, and they were all staring straight at him. There were no shouts or signs, but the indignation and infernal hatred of every person in the crowd was more than obvious.

His two foreign associates from the firm's subsidiary, Union Carbide of India Limited, stepped down off the stairs behind and joined him on the ground. Warren Anderson took a slow silent breath, and the three Union Carbide executives began to walk toward the crowd.

They had taken just a few paces when a group of five men emerged from the mob about 100 feet away and began walking toward them. Anderson's eyes turned quickly. This was obviously not a welcoming party of local politicians eager for their business. But something about their appearance suggested that they were not going to hurt them. They were reasonably well dressed, perhaps government officials. They continued walking toward the approaching men.

Their purpose became more clear as the group neared.

These people had their own point to make, and they were going to play it out in front of the media and the crowd. There were two agendas on the table - - his and theirs. But this was their turf, and it gave them an all too obvious advantage.

"Mr. Anderson?"

The group of five men stopped suddenly. The one who spoke was in front. Warren Anderson took two more steps, then stopped as well, face to face.

The accent was characteristically Indian, slightly high in pitch and staccato in its delivery. The man's voice was harsh. There were not going to be any pleasantries.

"Yes."

"We are officers of the Central Bureau of Investigations. Is this all of your party?"

Hearing who and what they were brought little surprise, but the abruptness of the question was disconcerting. This sounded a little more serious than anticipated.

"Yes."

There was a prolonged silence and everyone present absorbed the essence of what was about to be said, including, for the first time, Warren Anderson.

"Mr. Anderson, you and your associates are *under arrest* for conspiracy, criminal negligence, and criminal corporate liability as called for under Indian law. The three of you shall come with us."

Unbelievably, these people were really going to go through with this, and there was no choice but to go along. They were going to hold him personally responsible for what had happened at the pesticide plant! They were laying the blame on the parent company and, specifically, him!

Warren Anderson knew that the charges were part of an orchestrated media event, but no level of rationalization could quell the shock of being arrested. He knew also that the

maximum penalty for the crime for which he had just been charged was *death*.



A few days before, around 10:45 p.m. on the evening of December 2, 1984, Suman Dey, an operator at the Union Carbide pesticide plant in Bhopal, assumed his position in the control room for the start of the graveyard shift. As usual, Dey thought it would be a long and generally wearisome night, and there was no reason to suspect the occurrence of anything out of the ordinary. Like so many nights before, he would spend most of the long hours strolling up and down the panels, reading gauges, and entering data in the log book. But, he had to admit, some of the time would be passed in conversation with the other operators. It seemed that every night for the past month they had talked about the deteriorating conditions at the plant.

They weren't accomplishing anything by talking about it, he knew; but there was no denying that things had never been worse -- and there was some comfort in sharing one's problems with others. The company was continuing to cut their budgets, and it was taking a visible toll on operations. It had also begun to make his own job more difficult. Much of the control room instrumentation that told him what was going on out in the plant had gone unrepaired for months, and reports of leaking valves and pipes outside were becoming a nightly occurrence. The most upsetting part of it all had to be the layoffs. Fortunately for Dey and the other operators inside the control room, the maintenance people had taken the brunt of the personnel cutbacks. True, the demand for *Sevin*, the pesticide they manufactured, had declined over the years, and the plant was operating at a loss, but the company could run the place

better. Like so many of his trained colleagues, he would be gone by now if not for the incredibly poor market for his skills and knowledge. He should feel fortunate, to say the least, especially compared to the two hundred thousand people living in the shanty towns that had grown up around the plant in the last dozen years.

Dey began his nightly routine by walking to the high table in the middle of the room and opening the log book to review the activities of the previous shift. It summarized most of the day's major events, but the entries were often quite sketchy due to the operators' reluctance to write in English, as management required, instead of their native Hindi. A few hours before, according to the last scribbled entry in the log, the maintenance crew flushed the lines of the methyl isocyanate (MIC) unit with water. MIC, the main ingredient in the manufacture of *Sevin*, was stored in three large tanks outside. Flushing the lines was an operation that could be done only when they were not producing the pesticide, because the MIC was highly reactive with water. The long pipes connecting these tanks to other areas of the plant filled with residue over time and required flushing periodically with high-pressure blasts. The field operators, he hoped, had the wherewithal to show the new maintenance supervisor how the procedure was performed. Many maintenance jobs were being done poorly or not at all, now that the crews had been cut and the inexperienced people from the company's battery-manufacturing division had been put in charge.

A few minutes later at 11:00 p.m. it was time for Dey to walk back by the MIC panels and make his periodic check on the systems. He scanned the assortment of displays on the panels, including the pressure gauges for the three large underground tanks of MIC outside. The scale on the displays ranged from 0 to 55 psig, showing him the pounds of pressure per square inch

SET PHASERS ON STUN

above the normal atmospheric pressure. They had not manufactured any pesticide for many weeks, but it was still necessary to maintain a small amount of pressure inside the tanks in order to ensure that nothing, especially water, entered them. Tank 610 showed a pressure of 10 psig, just about in the middle of the acceptable range of 2 to 25 psig.



Unknown to Dey, the pressure inside the tank was 2 psig only 40 minutes before at 10:20. But the buildup was not apparent because no historical trace of the pressure was shown within the control room, and the operator on the previous shift had not entered this into the log.



As on every night at the plant, a small group of workers tended the maze of pipes, valves, pumps, and tanks outside the control room where Dey monitored the MIC systems. They had been quite busy outside for the past half hour, which Dey learned only when one of the newer field operators entered the control room around 11:30 p.m. The field operator was a short, middle-aged man, and he seemed like a well-meaning fellow, although he had not been on the job long enough for Dey to get to know him very well.

The operator did not appear to be too alarmed, just trying his best to make a clear report to the control room. Dey listened attentively as the field operator gave his report.

"It looks like we have an MIC leak outside. We weren't able to locate it at first, but then we heard it blowing near the scrubber."

Dey knew how MIC leaks were detected outside - - the

operators felt their eyes and then their throats and chests burn when there was a problem. Unlike their sister MIC plant in the United States, the Bhopal facility relied on the operators for leak detection. Throats, lungs, eyes, and ears were the gas sensors at this plant. There were no automated environmental monitoring systems outside, no gas sensors, no automatic alarms. They had to locate the source of escaping gas by seeing the plume or hearing a high-pressure screech. It was a difficult thing to do in the dark.

The field operator continued talking, and Dey listened carefully. "Well, when we saw the plume near the scrubber we went to the relief valve on the downstream side. Dirty water and MIC were flowing out the valve at a pretty good rate. The process safety valve has also been removed."

Dey, for the first time that evening, was moderately alarmed. He was also annoyed. He shook his head back and forth in mild disdain and looked upward momentarily, not at anything in particular. It was undoubtedly related to the maintenance crew on the previous shift and their washing of the lines. He thanked the field operator and told him to report back if anything else was found.



The MIC leak was relatively minor at this point in time and in and of itself was not of great concern. Small leaks, after all, were really quite common. What did disturb him, however, was the report that MIC and water leaked out of the relief valve. Under no circumstance should these two substances ever come into contact with each other. A mixture of water and MIC, he knew, could be very volatile.



Dey returned to the control room after a tea break about 45 minutes later. He did not talk about it during his break, but the persistent plume of MIC vapor outside and the discovery of water and MIC together in the connecting lines was bothersome. So, he walked directly past the 70-odd panels in the room over to the console containing the displays for the three MIC tanks. The pressure within Tanks 611 and 619 were just fine, but the pressure in Tank 610 was reading 25 to 30 psig, just beyond the edge of the acceptable range. When he had last looked at it, he recalled, it was 10 psig. Dey walked hurriedly across the room to talk with a colleague and get a second opinion. They both returned to the panel hardly a minute later and looked at the pressure gauge for tank 610. The needle was now "pegged" at the extreme end of the scale! Dey, as well as his colleague, knew this meant that the tank pressure had risen quickly to at least 55 psig -- and could be much higher, how much more they had no way of knowing. He headed directly toward the exit of the control room knowing that they might have a very serious problem on their hands.



Dey pushed open the heavy steel door, and the slightly cooler air from outside drew past him and into the building. Hesitating for a moment, he stopped and scanned the miles of pipes and equipment rising before him in the glow of the incandescent lights. There were no visible signs of trouble, but the burning in his eyes told him that they had a leak somewhere. He was concerned for his safety for the first time since beginning work at the plant.

The heavy steel door slammed shut with a loud bang, as if to

rudely prompt him into action. Dey started running in the direction of the MIC tanks; each footstep on the ground made a distinctive crunching sound, the only sound he noticed until he covered a few dozen yards and approached the MIC storage area where a venting safety valve was screeching. Slowing to a fast walk, he took a moment to catch his breath and survey the MIC storage area.

For safety reasons and to help maintain a low temperature on hot summer days, each of the double-walled stainless steel 15,000 gallon tanks was buried underneath a large rectangular slab of concrete. Tank 610 was under the slab at the far end. He broke into a run again, stopping alongside the concrete slab and pipes that extended from the tank underground. The relief safety valve was the one that had popped. Its graphite rupture disk must have given way, as it was designed to do when the pressure got too high. His first concern was knowing the temperature in the tank, something that was not displayed to him in the control room. The storage system was designed to keep the MIC relatively cool, so the maximum value on the round temperature gauge mounted to the pipes was just 77° F. Incredibly, the needle on the gauge was "pegged" at the 77° F mark, meaning that the temperature was at least that high. He looked next at the pressure gauge attached to the line with the relief valve that was venting the gas above his head. It read 55 psig, again, the maximum value on the scale.

Dey placed one foot up on the concrete slab and stepped up on to it. Oddly, he lost his balance and grabbed a nearby rail to steady himself. Once again he sensed that he had slipped and then realized that the huge concrete slab was shaking! He looked down and saw that the concrete slab on top of the tank - - the slab on which he was standing - - was cracking apart beneath his feet. It meant just one thing: an unprecedented, runaway chemical reaction was underway inside the tank. It contained

over 40,000 pounds of deadly methyl isocyanate (MIC)!

There was no way of knowing it at the time due to the inadequacy of his instrumentation, but the temperature in the tank was now well above 392° F. The maintenance crew that washed out the lines earlier that evening had failed, for a variety of reasons, to isolate tank 610 from the pipes they were cleaning with high-pressure water. Hundreds of pounds of water entered the tank and an enormous, volatile chemical reaction had been brewing ever since.



He jumped off the concrete slab onto the gravel and ran over to the vent gas scrubber a number of yards away where the MIC supervisor, Shakil Qureshi, and field workers were trying to figure out how to stop the MIC gas from escaping out the pressure relief valves. Dey shouted from some distance away as he ran toward them.

After a quick discussion, the small group of men rushed over to the MIC storage tanks. The concentration of MIC in the air had been increasing steadily, and Dey's lungs were starting to burn. Shakil Qureshi, relatively new to his job and generally unfamiliar with the MIC facility, surveyed the situation with Dey and then instructed the operators to isolate the leak by closing various valves in the network of pipes. There were no remote actuators in the control room - - all of the valving changes had to be made by the operators outside at the pipes, even when there was a dangerous leak such as this.

Their attempts were futile. The pressure within the pipes was far too great, and the gas blew past all of the valves, through the safety pressure rupture disks, and into the air from the web of lines around them.

Dey, knowing that a low temperature was important in

slowing this type of chemical reaction, shouted to Qureshi that they should get the refrigeration unit turned on. This system, situated adjacent to the three tanks, was normally left running in order to keep the MIC at a constant, cool temperature. If they could only reduce the temperature of the MIC, he reasoned, the pressure might subside and they would buy some time for figuring out what to do next. Dey ran over to the control panel and turned on the refrigeration system. It had been turned off many weeks before when they began their temporary shutdown of the plant. It never should have been turned off in the first place.

He flipped the starting switch, and the pumps came to life, slowly at first and then faster. The noise from the pumps became louder and louder with each passing second, but something was wrong. These were not normal sounds. Dey stared at the small control panel on the refrigeration unit and suddenly recalled that a maintenance crew had drained the coolant from this refrigeration unit some weeks before and used it in another part of the plant! There wasn't any coolant in the system because management didn't want to spend the money to purchase it. The pumps inside the refrigeration unit were pushing air - - not liquid coolant - - and were now on the verge of tearing themselves apart. He slammed his open hand against the metal control panel in anger, flipped the power switch off to shut down the refrigeration unit, ran back to the MIC tanks, and told Qureshi and the others that the unit was inoperable.

Like the other operators and his boss, Dey had never taken any emergency procedures training. He relied on his knowledge of the plant and his gut analysis of what they could do to solve the problem. He suggested to Qureshi that they pump the MIC in tank 610 into tank 619 which was kept relatively empty. Dey and Qureshi ran to the tank level meter only to find that it

showed the tank to be nearly full.¹ That wouldn't work either.

The situation had reached a critical stage, and Dey knew it was time to start up the major safety systems of the plant.

He shouted frantically to Qureshi, "I'm going to turn on the vent gas scrubber."

Qureshi directed the field operators to reroute the gas to the scrubber by repositioning valves just as Dey turned around and ran back towards the control room to activate the system. The safety device, located outside beyond the MIC tanks, looked much like a tall white rocket standing in the middle of the complex. It would neutralize the gas by showering it with a caustic soda as it passed through the tall vertical tank.

Dey burst through the doorway of the building and down the hall into the control room. The air inside was appreciably better than it was outside, and he inhaled deeply as he ran to the panel controlling the vent gas scrubber! He switched the system out of standby mode and turned on the recirculation pump. This would circulate the soda down through the tank and over the MIC gas as it was passed through.

Incredibly, something was wrong again! He reached up and tapped on the face of the flow meter display. This was the instrument that told him how much caustic soda was circulating down through the tank and over the MIC gas. There was no movement on the display. Nothing was flowing!² Dey

¹It was determined after the event that the tank *was* nearly empty and the gauge provided a highly inaccurate reading.

²A subsequent investigation showed that the soda was likely flowing through the scrubber and that the flow meter had failed to work due to lack of maintenance. Regardless, the scrubber was designed to neutralize a maximum of 190 pounds of gas per hour at 15 psig and a temperature of 95° F. The MIC entered the scrubber at a temperature in excess of 400° F and at a rate of over 40,000 pounds per hour, more than 200 times the design limit.

rushed out the control room once again knowing full well that their options were running out.



Bolting out of the building once again, Dey sprinted past the MIC storage tanks and out toward the tall vent gas scrubber, his lungs burning worse than ever. All of the field operators were standing by waiting for some sign that the system had been activated and the gas was being controlled or neutralized. Dey had not yet reached his co-workers near the scrubber when there was the sound of a loud crack against the backdrop of the screeching safety valves - - it was another rupture disk giving way. He stopped, looked up into the sky toward the source of the noise, and saw the enormous plume of MIC gas spewing out the end of a vertical pipe over 100 feet above his head. It was far worse than before. The chemical brew inside tank 610 was now over 400° F and pushing the gas through the pipes and out the tall vertical pipe at the phenomenal rate of more than 40,000 pounds per hour! There was far more energy than could be contained by the plant's plumbing, and the MIC facility was now nothing less than a runaway machine - - a machine that was spewing tens of thousand of pounds of poison vapor out into the night air.

Day ran to Qureshi, yelling above the noise of the gushing MIC vent 100 feet overhead.

"Let's divert it to the flare tower." He knew they had to act fast now; the plume was forming a massive cloud of gas which had begun to descend upon the plant and the surrounding area.



The flare tower was a near-final line of defense. Gas could be routed into the tall tower and ignited. It would make a high flame in the sky above the plant with the present flow rate of 40,000 pounds per hour, but the gas would be burned off in the fire.

Qureshi issued orders to the nearby field workers to prepare to turn the valves to re-route the flow to the tower where the gas would be channeled and then ignited. Dey followed him as they ran the dozen or so yards around the corner to the tower. Taking his last running step, Dey stared ahead at a large gaping hole in the side of the flare tower.

He screamed out: "Qureshi! It's missing. The connection is missing!"

There was a large round hole on the side of the flare tower where a pipe should have been connected. Dey realized that there was no way to get the MIC gas channeled over to the flare tower to be ignited. Their most foolproof safety system could not be activated. Dey did not know that maintenance workers had removed the corroded connecting pipe a number of weeks before. It had never been replaced.

The plant superintendent, who had just arrived at the facility and joined the group, ordered the alarm system activated. A field worker ran back into the control room to pass the word. The alarms blared, alerting the 120 employees on duty to evacuate, and Dey stood outside in the dark under the billowing cloud of poison gas watching the doors explode open and the silhouettes of workers spilling out into the yard. Some stopped momentarily and looked up at the huge gray plume in the dark sky. Then they rushed headlong to the gate and then north, into the light breeze and away from the cloud that was forming above the rooftops of Bhopal.



There was just one final thing that they could do: turn on the water curtain. This was a system of high pressure water pipes and nozzles that would spray a curtain of water over the plant and, again, neutralize escaping gas. Dey directed Qureshi and those remaining to open the valves to the water lines. The spray nozzles, each like the end of a fireman's hose, were pre-positioned to blanket the entire production facility in a shower of water.

The first pulses of water rushed through the lines and then spurted through the nozzles a few feet. The pressure increased quickly and a blasting shower of rain enveloped the facility. Suman Dey was too exhausted to notice or care that he was soaking wet within a few seconds. He placed his hand above his eyes to shelter them from the pelting spray of water and looked up into the sky. There stood the tall pipe and the spewing plume of deadly MIC. He lowered his hand and rubbed his wet face, fully aware that the massive spray of water was not powerful enough to reach the gas plume. The hole from which the gas streamed was more than 100 feet above the ground and the water curtain reached only 40 feet up into the air - 60 feet short. He knew he had to leave now if he wanted to stay alive. Dey ran along across the wet gravel toward the gate and then through the dark alleyways of the extended ghetto and to the north. He did not stop until he had reached the isolated mountains well outside the city.



The escaping cloud of methyl isocyanate descended upon the sleeping residents of the densely inhabited neighborhoods surrounding the plant. Some residents awoke with searing eyes and lungs, only to suffocate and die while running through the dark and narrow alleyways between their makeshift homes.

Others suffocated in their sleep, drowning in the fluids excreted by their own lungs. The final count was never known, but at least 2,500 residents of Bhopal died in the early morning hours of December 3, 1984. Tens of thousands more suffered irreparable respiratory and neurological damage. Suman Dey and all of his co-workers at the plant survived.



After their arrest at the airport, Warren Anderson and his colleagues were taken to Union Carbide's comfortable guest house, protected from the mob outside by 50 armed guards. Released six hours later on \$2,500 bond, he made a statement to the press. His speech demonstrated his honest concern for the victims, but also revealed his level of understanding of the causes: "...our safety standards in the U.S. are identical to those in India or Brazil or some place else. Same equipment, same design, same everything."

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