ZULFIKAR CUMALI

ASHRAE LEADERSHIP VOICES

Jeff Habrel: Good evening. My name is Jeff Habrel. I'm an ASHRAE Fellow and former member of the ASHRAE Historical Society. It's my pleasure today to interview Mr. Zulfi Cumali. Zulfi's a long- long-term, well-known ASHRAE member. And, if you don't mind, Zulfi, I'd like to start by having you give us a brief review of your life, and where you're born, your education, and how you got into HVAC business.

Zulfi Cumali: Thank you. Okay, I was born in 1933 in a small town in Turkey named Merzifon, and my family got there from Greece, some of the original Ottoman Turks that went to Greece in the 14th century, and then they settled there. In 1924, there was an exchange of populations after the First World War, and then they moved to Anatolia. My father picked the small town Merzifon because they had some exchange lands and properties, and also, I think, the fact that there was an American missionary college there. So, he picked it up so that the capability for their children to have education, you know, was of importance to him. So anyway, I went to primary school there. We had a farm and a flour mill, and I spent some time there working in the fields, also working in the flour mill shop, trying to create electrical motors that generate electricity, which never worked, but I learned a lot about electricity. So, then I went primary school there in Merzifon. And then, in 1949, my father passed away, and we were, before then, moved to Istanbul from Merzifon. I was sent to a English high school, a premier school of the time, which had acceptance criteria for both American and European universities. So, I went there for six years and graduated there with honors. And then, the idea was that when I was a little kid, I would learn how to read very early, and then I remember reading a ten-volume children's encyclopedia, and it excited me to see that all these people were building these buildings, airplanes, and machines. That kind of decided me how to be, why I should be an engineer.

So, I followed on that and went to Robert College Engineering School in Istanbul for a year. And then I was trying to decide whether I should go to the United States or England for my university studies, and it turns out that my brothers-in-law, two of them, one of them was a naval architect, a graduate of MIT, and the other one was a mechanical engineer from the University of Manchester. So, they said, "Well, where do you want to go?" I said, "Well, maybe MIT or Cambridge." And they said, "No, no, no, that's not where you want to go. We recommend that you go to University of California in Berkeley, because that's one of the premier engineering schools. It has a very nice climate, good for studying. And in the cosmopolitan environment, the Bay Area, you can have a good time." So that's why I got ended up in the Bay Area.

But in order to get out of Turkey, you have to need an exit visa, and the exit visa required that you have to have a definite area of study. And that happened to be food technology, and food technology was offered in the University of California, Davis. So, I went there for a year. And, you know, a little trickery, after a year, I changed my course of study to process engineering, which was a combination of chemical and mechanical engineering.

So, I transferred to Berkeley, and I was, as a junior, and I studied there for a couple of years. And the thing I remember most is that in the last year, I had a project, which was the design of a natural gas liquefaction plant and storage and transportation of it. So, I really enjoyed how to formulate that, how to do the different refrigeration cycles and how to optimize the different ways of doing it. So, that sort of got me really interested in modeling and simulation. That was sort of a big impetus.

Then I graduated from Berkeley with a degree in process engineering, which was 1956. And then, I had a one-year work visa, so the opportunities for work for somebody with a one-year visa was limited. So, I ended up working for a startup, a small company called Cason and Goodman Associates. They had just started; I was their second employee. So, I worked for them for a year, and after a year, they ran out of work, so I had to go and work for someplace else.

So, in the meanwhile, I studied and got my mechanical engineering license from the State of California, and I decided that I just really wanted to go to graduate school because I wanted to do interesting stuff. Anyway, I started in Berkeley. And I spent four years in Berkeley. It was one of the best times of my life because I was able to work part-time for the consulting firm, make a living, and then take all the courses that I wanted. And I took, I don't know, as many courses as I did in more than my undergraduate degree in graduate school. Oh, I took hydrodynamics, theoretical hydrodynamics, quantum mechanics, astrophysics, quantum mechanics, as well as the usual courses and all the math stuff required to do this kind of thing. So, I really enjoyed it.

So, one of my thesis subjects was on finding the transport properties of liquid metals from a molecular structure point of view. So, you look at the structure of the molecules and, from all the relationships, by using quantum mechanics and statistical mechanics, try to find out what those properties were. And the reason for that is, at the time, nuclear reactors were using liquid metals for cooling, and this was the reason for the interest in that area. So, one summer I worked for Bechtel, a nuclear engineering division, and did the, modeling for, the flow network for the liquid-sodium-cooled reactor. That was kind of interesting, and one of my classmates also worked there, and then he ended up being one of the big chiefs in Argonne National Lab.

So, in any case, at the end of the spirit, it got to a point that, well, I had met a very pretty Canadian student, and married, and we had a son, and then, one thing led to another, and then I realized that for what I was going to would be, Academic career starting as an assistant professor at a university, and my income was way beyond that doing consulting, so I naturally tended to move into the consulting, plus the fact that there was a big fight against nuclear reactors at that time. So, I moved and went back into consulting and started working on different kinds of problems.

Jeff Habrel: You know, how did you first become interested in HVAC?

Zulfi Cumali: Well, I didn't take a formal course in HVAC, but in chemical engineering, you have unit processes, and unit processes cover all the things that are involved in air conditioning and et cetera, because you do that for large chemical plants. And plus, my original interest in the liquefaction plant and the ability to formulate and solve such problems is what got me into it. That's kind of interesting because in Berkeley, I went to a class in Fortran programming at the time. And I attended three lectures, and I decided they were too slow. And I just got the manual and started working on that. Yeah, and then, and it just went on.

Like, one of the things that happened earlier was that I was working on a hospital and then the hospital had a problem: you had to select 500 heating coils and 60 cooling coils. And then the tradition at the time was that as an engineer in an engineering firm, you did the calculations, and they gave the selection of the equipment to the manufacturer. So, the manufacturer made the selection of the equipment, and typically they were one or two sizes larger. And my boss at the time, Carl Gutmann, was a Viennese, and he was very open-minded, quite a good engineer. He gave me the latitude; he said, “You know, you do what you have to do.” So, anyway, to select these coils, I created a nomograph so I could just select them.

Well, what ended up happening is that the coil sizes were one or two sizes smaller, and therefore the piping systems were smaller, and therefore the cost of the project was smaller. So that led to essentially programming that, and that was my first program: how to select heating and cooling coils. An interesting episode in that, in order to do that, both the nomogram and the program, The manufacturers would not give me any of the heat transfer coefficients of these coils. They thought it was proprietary. And I said, “That’s, I’m not gonna live with that.” So, what I did was I reversed engineered from their catalog data, extracted the information, and then used it that way. So, that, and there were some other problems that were very nonlinear. For example, how to calculate the climate, pardon me, the ambient conditions in a hospital room with openable windows in the San Francisco climate. Well, that’s sort of a difficult problem to do. So, it was difficult to solve that with hand calculators and slide rules.

Jeff Habrel: Didn’t you actually teach computational classes at University of California?

Zulfi Cumali: Yeah, at the time there was some interest in computer applications. And then, I started teaching a course in computer applications in HVAC, and then I taught that for two years.

And the, it was interesting. There was a lot of principals of firms who would attend. Owners of the firms. Owners of the firms. And some of them were my old bosses, which was kind of interesting. So, in any case, that always led into some interesting arguments saying that, you know, from experience they thought it was this, and from a calculation point I would say it was this.

Jeff Habrel: From some of the hospital designs that you did, do you remember some of the aspects of the design process and what it was that you ended up installing?

Zulfi Cumali: The hospitals are probably the most complex buildings that you can build. Cason and Goodman used to do a fair number of hospitals, and they were specialists in that. So, at once I started my own firm and I started looking into not only the problem of mechanical engineering systems in a hospital, but also looking at the electrical, looking at the way the layouts were made. And so, trying to establish a relationship for design between all the professionals that included in the design of a hospital.

So, one of the things was that there was a hospital project, a thousand-bed hospital for military in California. And then we said, well, let's look at what the influence of layout is on all the systems that we're going to design. Yeah. And then, so I got a doctor and some help. We said, let's start with the kind of, operations that take place in a hospital. We have so many cases of a certain type, and each case requires so many sequential operations before a person comes in and gets out of the hospital. So, we did this for patients, for the doctors, for the nurses, and all the personnel in the hospital, and created a huge network of what goes on in the hospital.

We were nurses and everything else, including the HVAC. Yeah, so, the interesting thing is that the architects would give us layouts, and we would apply this criteria on the layouts, and one that was very interesting, the difference between one layout and another that we got was 200 people doing nothing but walking eight hours a day. Well, 200 people. So, our HVAC system went into it because we were able to reduce the design to modules. And each module had a system. We broke it down into modules. And then we look at the interconnection between the modules so that we could determine what kind of flows, energy flow medical gas flow, electricity, etc., going from one to the other. So that also configured in the design of the hospital layout.

Jeff Habrel: Now this was the consultant's computation drill? Ok so that was your private firm.

Zulfi Cumali: That was my private firm that I formed in 1967.

Jeff Habrel: And didn't ASHRAE have procedures for doing this? Why didn't you use the ASHRAE procedures?

Zulfi Cumali: Well, ASHRAE procedures at the time were kind of primitive. Tabulated values in which you got in, etc. And it wasn't very satisfactory. I mean, you could do a quick calculation, but you couldn’t do annual stuff easily, and other than using the bin method, which I did not think was very efficient.

But in any case, what happened is that he was interested in transform techniques. That means that the building, Yeah, yeah, is as an input which is diurnal, which is daily cycles; and then the people come in and go out. They're all based on cycles; therefore, you can use the cyclic approach to solving the problem. So, at the time I had met a gentleman who discovered the fast Fourier transform by the name of Gordon Sandy, and then he gave me all the very interesting routines for making fast Fourier calculations, and that I could apply to annual weather data, smaller amounts of weather data, or other kinds of solutions.

In any case, I thought this was good, and I tried to get interest from ASHRAE to see if they would be. Well, I sent a letter to the task group on energy requirements, Task Group on Energy Requirements. Well, I sent it to the group, and then I got a response from Metin Lokmanhekim. He's the one that developed the Post Office program. And, he said, "Well, they asked me to call you because you sent a letter, and they didn't understand. They wanted me to talk to you." Yes, yes, so that was kind of interesting. So, I went to the task group meetings several times, but the task group was run by Mr. Tull, who was the past president of the society. He didn't want another young Turk in this, in the group. And he well, Kusuda was interested in my approach, and he said, "Hey, why don't you come to NBS?" And I went there for a summer. It was interesting.

The family went to Europe, and then I thought this was a good idea. I could just spend some time in Washington, D.C. And he and I had a good time playing with their high-speed computer at the time. And then we did some work on weather data and then how to simplify weather data and how to apply this, and we published a couple of papers. But something very interesting happened there. You know, when you do Fourier transforms, you know, you have to take loop after loop after loop. Like if you do 1,000 items, you need 10 levels of dual loops. If you do a yearly thing, you need about 15.

Well, their Fortran compiler wouldn't do dual loops that deep, so we had to find out why it wasn't working. Then there was a gentleman who did this. That was an interesting simplifying no, just to make the machine work, just to make loops work. So anyway, I liked Kusuda. I really enjoyed working with him. I'm sorry he was hit by a truck and died in an accident, but he was a major contributor to ASHRAE.

In any case, after that, I applied this hospital thing to other hospitals. In the meanwhile, the post office program: there were two requests for proposals from the post office. This was about 1969, I believe, or ’68 something like that. I responded to both, and then Metin's group got the programming part, and we were called in to do the part where we would actually instrument a building and find that the results of the computer program were accurate. We somehow went to Washington, D.C., and were interviewed, but then we didn't get it, even though the interview went very well, partly because my partner, Carl Gutmann, was a Viennese and I was a Turk. At the time, the Israelis and the Arabs were having a fight; they thought they would carry the fight into the firm. Therefore, we would consider the risk. So it was that kind of thinking going on at that time.

In any case, the post office program was published about a year and a half later, I think early 1970, and I took the program and took a look at it. It had several difficulties in that, in order to run a building in it, you had to dimension all the variables in it that would fit that building; therefore, you had to recompile the program for each building. That certainly wasn't satisfactory, plus the fact that it was written in an unusual style in that they had very, very long routines, like a thousand or more lines at a time, very cumbersome. So, I recall splitting it up into about 17 different parts, then separating all the variables, and in order to overcome that sizing problem, I just made a linear list, put all the variables in the list, and then put pointers to it. That way, I got the make-one change in the variables to fit whatever problem you had. And we added additional systems to it. There wasn't much. And we also had plant section to it.

And in the meanwhile, I was doing a lot of work with Bentley engineers, looking at total energy plants and cogeneration that's required for groups of buildings or building complexes. And I worked on that for about a couple of years and came up with an extensive report on how to design such things and how to arrive at optimal designs and optimal operations. Yeah, cogeneration systems.

And then that became a project that I got about eight years later, a big project from Argonne National Lab on community systems and how integrated, yeah, yeah, that one. So, in any case, while we were doing this, then one day there was a program that Art Rosenfeld, who was at LBL, had a three-day conference. That's, yeah, in 1975. So I attended this conference, and it was very interesting. There were lots of people. Most of them were trying to find out what was going on, and some of them had done some work on it.

So, I remember asking a few questions the first day. The second day, for some reason, the questions were pointed at me. And the third day, I was answering all the questions. So, at the end of this conference, Art came to me and said, "You seem to know something about this business, so why don't we raise some money and like, get a program?" So, Art managed to raise half a million dollars from ERDA, which is the Energy Research and Development Administration, the predecessor of DOE and the California Energy Commission and that was the Cal-ERDA program. So, we started, in 1976, we started the project, and then he also got additional funds. That involved Argonne which did the user manuals, and Los Alamos, which did the technical manuals.

Zulfi Cumali: Yeah, that was Larry Degelman, who was professor at University of Pennsylvania.

Jeff Habrel: Penn State. Penn State.

Zulfi Cumali: Sorry for the confusion Yeah. And so, he says, “Zulfi, let’s get, see if we can get some National Science Foundation funds.” So, I think he got about $150,000 at that time. So, I was a consultant to that group, and we just basically produced a report on how weather data could be used in energy calculations and how it could be.

The basic thing is that everybody was trying to use hourly weather data, 8,760 units, plus, you know, five or six variables. And I didn’t think it was necessary to have that, but what one can do by simply analyzing the cyclic nature of the weather data, you could actually create weather data much shorter; you can synthesize it, which has identical statistical properties, maxima, minima, and you could do it in approximately one-fifth the time or one-tenth the time to come up with....well, they had they weren’t available for every other place. And you could create weather data, you know. Yeah, this was one.

So then, I got a project from the weather data committee from ASHRAE to select typical-year data from 10-year, 20-year, or 30-year data. So, I started that project, but they didn’t want me to use synthetic data; they just wanted to use actual data, real data. So, they wanted me to select it month by month. I did the selection month by month. And then what happened is that the end points, because the months were selected from different areas, didn’t match. So, they said, “Well, that’s not good enough.” I said, “Well, I could smooth all that, make all that.” And the answer was that you had to be a certified meteorologist to make that match. So that...

No. There were two meteorologists from the Army Corps of Engineers, and they were adamant that engineers knew nothing about weather data; therefore, they couldn’t do it. So, anyway, we passed that hurdle and passed the DOE II project. Yeah, the one. Well, the thing about that was most people used tabular input. And then I decided that you have to have a free form input free, yeah, like a sentence structure. In that you have to have a label and the value: label and the value. And you could combine them into, like, these are the words; you can combine them into sentences. Yeah, and you could be like a wall this, and then this wall belonged to a zone. This zone had this many thesis. That was the beginning of the building description language. And the fact was that you could actually, using this language, not only create the input but you could create input for as much complexity as you wanted. Yeah, and also you could create essentially a building by combining them together. You didn’t have to recompile the program or anything like that. So, this, yeah, this was a, this was a separate compiler to create the input for the program.

Jeff Habrel: Very interesting. Yeah. And how did this figure in with some of the work you did for the U.S. Army Corps of Engineers on the glass corner?

Zulfi Cumali: The BLAST program at, we were to some degree competing with the BLAST program at the time. But then it turned out that DOE decided to go with us, and the BLAST program didn’t have any, a plant program. So, they purchased the plant program portion of, our software to put into the BLAST program. That’s how the interaction took place.

So, by 1980, our work was done at Lawrence Berkeley Lab, and then they decided to take over the work. So, which was a little surprise to us, but anyway, I was looking to do other things, and one of the things that happened in the meanwhile was California Energy Commission was putting together an energy conservation code for the state called Title 24. And I was on the advisory committee on that. And we used the program to generate the required energy budgets. The O1 program. To create all the energy budgets for the state. And then, at the same time, I didn’t like the user manual that Argonne was developing. I developed a graphical user input. Yeah, so that you could actually see all the words, the sentences, and the structures that you get on all different parts, load systems, plant, equipment, you know, economics, essentially. So, I did that, and we put the program up on control data service centers for about three years.

Jeff Habrel: This is a computer.

Zulfi Cumali: Yeah, and there was some push to make the program run on smaller machines, and I fought against that, thinking that the computer power would catch up with us, because we have to do the, solve the problem properly to the, yeah, and go on that basis. Then, I was looking for a project or projects to take these programs and apply them into actual running of buildings. So, was that the beginning of some of your optimization? Yes, yes. I was, as I say, worked with Bentley Engineers, and which is a larger control I mean, design firm.

And they had designed the Embarcadero Center in San Francisco, which is a four-high-rise complex. And then I was involved in that phase, but then later, we contact, the complex was owned by the Prudential Insurance Company at the time. And then I talked to the chief engineer and then told him that they were gonna get a new EMCS system.

One of the things I could do was get a new EMCS system and at the same time use the system to run the buildings optimally. Yeah. The whole idea is, was that I could simulate the building operation, make a model, and use that model to send it to the EMCS system, and have the EMCS system meet the requirements I created. Yeah. So therefore, it was a, predictive control scheme. So, we're, oh, you name it: the control, the person who was the chief engineer for the building didn't want to have anything to do with us. He wanted to select his own EMCS, vendor, and we had a different one in mind, and then he thought us all by this time, the Prudential engineer decided that he was going to go with us, and the guy was still objecting to it, and they had to put him to the side, so they put somebody new to work with us.

So, anyway, that was one area, and the other one was, at the time, large control companies, Honeywell, Johnson, and so, were the ones who had EMCS systems that were on these buildings. So, the bids that they got from these firms were way high, but then they only measured temperatures and some simple things, but they did not measure flows.

In order to do optimization and building, you have to be able to measure energy consumed. Not just at the meter, but at different places in the building. So, none of the bids included such measurements. So, I selected a local EMCS contractor or manufacturer, and they had adequate capabilities, and they were willing to work with us and to add additional capabilities so that we could get information, get exchange information with their computers. So that was the first one: how to get the information in and out. With the EMCS system and getting into the modeling scheme that we had, we used two sun-two workstations-sun works-sun two workstations for each building to do the optimization. We've published a couple of papers on those. And then some of the problems we had was the machines weren't fast enough, so we had to add array processors to improve their speed. Yeah, exactly. Yeah.

So then, the other one was the communication problem: 5,000 feet from building to building. So, you had to use different Ethernet, and then we had to write special Ethernet codes for the communication. These were some of the barriers. The biggest ones were how to do the measurements on large air-air ducts fans, large pumps, and cooling towers, because those measurements are very expensive, and we had to be very innovative in making those measurements so that they were at the right place, and we did some of them directly, some of them by implicit, you know, assumptions, making measurements by calibrating something beforehand, putting one item on it, and then getting the rest of it.

So those were some of the big ones, but it was a very successful project in the sense that it took a couple of million dollars in two years, and then we were able to save a significant amount of energy to justify it. Yes, controlling the building better. So, this, I believe, was the first application of optimal operation in a building of this size in the United States. So, yes. They never stop. And well, one of the new ideas is that you have all these people making thousands of runs, either for optimization or finding certain features of buildings and building complexes. And then if you take a building and a building has maybe 30 parameters, the number of runs to cover the search space is in the trillions. So, there's no way you can arrive at some kind of a solution.

So, one of the things I was working on and looking at these days is one you can reduce the dimensional space by a factor of three or five or more by looking at combination of variables, especially the kind of variables you see in heat transfer, like Reynolds number and Brown number, et cetera. Some combination of variables still represent, you know, the relationships in a building. So, there's one. And the other one is something called gauge theory that physicists use where you look at systems where the force relations between the units or components are many orders of magnitude large. They can look at gravitation, which is very weak, versus molecular forces, which is next, then nuclear forces, which are much. So, there's huge, maybe 10 or 20 orders of magnitude in these.

The point is that this allows a rational way of making comparisons among different kinds of buildings. If you look at buildings from high rises to a residence, so you have this large. So, combining the reduction in dimensions with this, I think, might give a very interesting and compact relationship. So that's one area I'm working on.

And another area is in graph theory. That means, I'm always interested in being able to create the shape of a building, okay, and having the shape related to the equations in which you are making the calculations. So, there's an inverse and direct relationship in things like this. And some of the ideas that come across, as you know, you have in crystallography, where you have these atoms at different places and then they have different formulations. And some of these formulations are such that each term in the series represent a shape of one sort or another.

So this, some kind of an interesting idea that you can write equations and create building shapes. So, and then also use the same thing for doing the calculations. And plus, the fact that you can use that optimization because in, While you're doing the calculations, you can change shapes. So, it's a fascinating idea. Anyway, this is another area I'm looking at. And in the meanwhile, I'm looking at the current calculations: I did the DOE 2 and the DOE 1, and then there's the current, Energy Plus. And there's a vast difference in speed between these two programs. And, for some reason, Energy Plus runs very slow. Yeah, and I call it the product of the iteration school.

In Energy Plus, there's about five or more layers of iteration. People don't solve the problem; they solve it by iteration. And then in Cal-Order and SERA, my instruction to my people was that you take a formula, and you have to tell me whether it's linear, or non-linear, or it's n-square, n-to-do-or-do-or-exponential; you have to tell me how many operations it takes to solve it. Until you do that, you can't put a single line of code. So that was the basis, and that's why it runs so much faster.

Jeff Habrel: Any final words of advice for your fellow ASHRAE members? Any final thoughts?

Zulfi Cumali: I do. Why does it take so long to get things done? Last night, I went to a conference, to a meeting at IPSA, and then people came up representing how the energy analysis should be done on buildings. And my attitude was that in my office in 1980, my scope of services I offered to my clients was the same. That was 35 years ago. And usually, things take typically 10 to 20 years to percolate, and ASHRAE has a lot of young people, bright people, and this process has to be speeded up, and I find that very difficult to accept.

Jeff Habrel: Zulfi, I want to say that I've enjoyed this very much. I want to thank you for your time and your efforts and service to ASHRAE.

Zulfi Cumali: Thank you and it was a pleasure.