PALO VERDE

RE-ENGINEERED MET SYSTEM

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The Re-engineered Meterorological Data Transmission System (hardware)

INTRODUCTION

In late 1994, having returned to my home organization after a 9 month temporary assignment with Equipment Qualification Engineering, I was assigned engineering responsibility for the Meterorological Data Transmission System (MDTS). The responsibility for this system had been passed on from organization to organization during the past 15 years and now my home department, Operations Computer Systems (OCS) had the ball. OCS is unique in that it provides engineering and maintenance under one umbrella. Engineering consists of both hardware and software, and the hardware engineers such as myself, are responsible for system, maintenance, and design engineering. This arrangement provides an ideal environment for the seamless integration of skills and personnel, or, in the current "Newspeak", Project Teams. This paper will describe in a brief way the methodology and thought behind the upgrade of our meteorological computer system.

PROBLEMS

Discussing the overall system situation with my supervisor, the technicians who were providing maintenance, and the PVNGS meteorologist, the following became evident: I had inherited a low visibility, high maintenance system with many unresolved problems, and one very unhappy and somewhat hostile meteorologist, Dean Peckham.

Discussions with Dean, several maintenance technicians, and the software engineer who had been providing some support on the system revealed several key issues that resulted in my decision to totally redesign the digital processing hardware component of the MDTS and provide some relief for various other bugs.

Among these were significant maintenance issues regarding the constant attention required to keep the four chart recorders working properly. These were well past end-of-life and spare parts were becoming far and few between. The Dec PDP 11/23 computer, also past end-of-life was running under proprietary software, and any required or desired modification to the application software was accomplished with great difficulty. Related to this was the fact that there were many identified "bugs" and operations that were undesirable.

The telephone lines connected to the MDTS suffered major degradation whenever it rained. This degradation interrupted data transmission to the Emergency Radiological Facility Data Acquisition Display System (ERFDADS), as well as the dialup circuit utilized by Dean to extract stored data. In fact, these lines were so rotten that 300 baud was the limit to data communications. As rain might be considered to be the exception rather than the rule in the Sonoran Desert, to date nothing had been done to initiate serious repair on these subterranean lines. Mains power was a problem; the system is supplied offsite power and during times of storm activity it was not unusual to lose power. Prior to OCS involvement, the I&C Engineering department had provided a quote of approximately $100K to provide a source of onsite power. The local joke was that this would be "the world's most expensive extension cord", and was not treated seriously by anyone with the ability to provide funds towards this end.

Related to data collection, one of the major problems was the method in which the system had been originally setup. The equipment tower supports 10 meter and 60 meter levels of primary and redundant sensors. Simply put, if any one sensor of the same type on either level is malfunctioning, the system would declare all data of this type at this level to be invalid. The provided line printer output would simply not provide the data, good or otherwise in the appropriate field. A number code only would be inserted, which would be translated to indicate the lack of available data for this parameter. Of course the analog strip chart records could be cross referenced, but this was a very time intensive process. Adding to this the various problems with the ancient strip chart recorders, the problem was compounded greatly. It was now time to roll up my sleeves and see what could be done to provide a remedy for these problems and befriend my chagrined customer.

One other problem existed that would determine the course of action; funds. The "owners" of the system, Radiological Monitoring, had only $15K to pitch in.

SOLUTION(S) and DEVELOPMENT METHODOLOGY

Prior to actual involvement with the system problems I decided that since we were now coming into our "rainy" season, it would be prudent to initially address the phone line problems. Curing this would, at least, allow data retrieval to continue and take some imminent pressure off for a while. Directly related to this cable degradation was the limit of 300 baud that the link could, without error, transfer data. Investigation into the problem revealed that about 100 yards of subterranean line feeding the MDTS equipment shelter would collect moisture and over the years this section of line was, for all intents and purpose, rotten. The cable was encased in a rubber-like insulation which was, in turn, fed through concrete duct bank. It was not possible or practical to pull the cable out to replace it because the cable would simply pull apart. Pulling additional cable through the same concrete conduit would most likely provide similar results, and put us in an action statement. There is a 72 hour Action Statement associated with the Technical Specifications regarding the MDTS, and it was doubtful that the work could be coordinated and completed in time to make this deadline. I also had reservations in being the person responsible for putting us in this situation. Needless to mention, cost was an issue as well. Quotes from the various site organizations required to provide these services ranged up to $50K.

At this time I embarked on a campaign to simply add another phone cable parallel to the existing line, but not encased in concrete Duct bank. Since the area of replacement was not inside the Protected Area, but actually in open desert, providing cable encased in duct bank was not a requirement. Phone calls and much begging got us a couple of hundred yards worth of scrap Schedule 40 3" PVC and enough salvaged high quality 26 pair phone cable to do the job. It was decided to lay this out as close to an existing above ground Telco terminal box that could provide connection to the necessary plant circuits as possible and still provide a means of getting to another dry end of the defective cable. The plan was to get this in place and then simply cut out the defective cable and splice the new stuff in, thus providing minimum impact to the associated systems and personnel. Further begging resulted in a trench being dug by fellows with access to the proper equipment about 10 foot from the existing path between the Telco box and a manhole about 130 yards down the line that provided a route to the MDTS shelter phone lines. Perfect! The maintenance techs were busy with outage work, so the OCS engineers were enlisted to lay the PVC conduit and pull the cable. This work now being completed in about a total time of 6 hours by 9 of us, all that remained was the connection of the new cable. Our friendly site telephone technician accomplished this in short order, and we were now back in business. The total time without phone lines to the system was less than 1 hour, and with the need for some PVC elbows and cement that were not available on site, the capitol expense was less than $20.

Mains power to the MDTS shelter was a prime issue to address. An associate who is currently employed as a sales engineer for an electrical/electronic distributer aided in selecting an uninterruptable power system that was within the budget. This particular device would be supplying power via its inverter full time, and with two auxiliary batteries in addition to the standard internal battery would provide power to the 4 dataloggers, 4 multiplexers, analog signal processors,2 dialup modems, and 2 shorthaul modems for no less than 24 hours if the mains should drop. The air-conditioning was not really an issue with the Campbell equipment as it was with the DEC computer. The cost of this device and batteries was ~$1500. Problem solved.

In keeping with the new philosophy, a project team was formed. I chose Senior Technicians Vaughn Lee and Gene Penick, Work Planner Mike Barnes, software engineer Jerry Dudley, and, after an initial "brainstorming session, it was decided we could pull this job off during the allotted time period. I deviated from what is, in my experience, normal practice in that I decided to let everyone on the team play a major role in the design details and basically "have at it", assuming they remain within my original design guidelines. These guidelines were to remain somewhat flexible, acknowledging that everyone on the team would have productive and useful ideas. I basically provided the overall design and the hardware that would be utilized, and ALL of us would work together fill in the blanks between the input and the output.

It was obvious that major changes would be necessary to deal with the data processing problems. I had inherited from the last engineer responsible for the system a quote from one company that proposed replacement of the DEC computer with an IBM personal computer or clone and the price hovered around $60K, including specialized application software. This did not appear to be too far out of line, but kept us tied to outside vendors for hardware and software support. With existing talent in our own house, this didn't seem to be the way to go and in order to complete this task within the allowed budget it became obvious that we must deviate from the computer replacement paradigm.

Research among colleagues and various vendors pointed towards substitution of the computer with a specialized data acquisition system, and I eventually ended up in conversation with Charley Mondale, applications engineer at Campbell Scientific Systems. These folks provide various dataloggers designed for remote unattended meteorological data acquisition and based on our requirements and proposed capitol budget, which at this time was only $15K, the prices of Campbell's equipment was very attractive.

It seemed certain that $15K would not quite pay for the scheme that was developing and I was eventually able to coax another $8K from two other site organizations, Operations and Emergency Planning. Unit 1 Operations, according to tech specs must check and record weather conditions on a daily basis via ERFDADS terminals, and if ERFDADS is unable to display the required meterorological data, a trip must be made out to the MDTS shelter to obtain this data locally. Usually the circumstances that generated this condition were loss of power due to a storm. So we were now committed to providing constant power to what I promised would be a rock-solid system. And we had $23K to do this.

Having tentatively decided on the dataloggers for a base system, I devised a basic architecture that would provide backup in the event that a single data logger failed. This developed into a backup for the dialup lines and the ERFDADS direct connect lines. The little Campbell CR10 datalogger was more or less decided on based on price, but could not support the number of required inputs. It was decided at this time to add to each data logger a Campbell Scientific Company AT25 Thermocouple Multiplexer to each datalogger, thus expanding the amount of input channels to a number far greater than we had present need for. Since our analog processors provide a 0-+5VDC output and the CR10 Datalogger inputs operate on 0-+2.5VDC, Campbell engineers provided an active voltage divider circuit for no additional charge.

The dataloggers utilize their own ROM-based "operating system" and for minimal cost we obtained, from Campbell, DOS based application software to arrange and download our own procedural command software. This software package also provides means in which to extract data in various formats as well as trending and chart applications. Campbell also provides a "suite" of peripherals that mate with the CR10 Datalogger. These are very reasonably priced and very low current drain to allow for long unattended operation in remote sites.

It was decided originally that the engineers would take on the software development task, but Vaughn expressed interest in this task. Prior even to any final decisions on the base architecture, he had produced the bulk of the required code. Dean's co-worker, Josh Morrison, became active in the software development at this time and teamed up with Vaughn to finish up this task, providing information and code development assistance to tailor the software to conform to the final system specifications and requirements.

As the MDTS sensor data was presented to the DEC computer via a barrier block connection it was no problem connecting the Dataloggers to this same bus for testing and evaluation, not disturbing the original system. The ability to test and develop this system with real data in the final operating environment was a major key to the project development and eventual ease in cutting over from the DEC computer.

With access to a CAD station obtained, we created the electrical schematics as the design progressed. The original is an overall block diagram, and the additional prints break down the block to its individual four subsystems, with the last and 6th sheet being a "catch all" with specific details, charts, and other pertinent data. Documenting the design as we went along allowed design changes to be incorporated on the fly and essentially bypassed the PVNGS records department until the design was frozen, saving the processing time and allowing us flexibility with the design. Schematics were laid out with maintenance in mind and used a combination of graphic images of the actual devices as well as lines to denote connections. These 6 C-size sheets allow troubleshooting of the digital subsection of the MDTS with no supporting documentation being required, eliminating the requirement for what was many sheets and documents. Graphic images of the hardware on these prints define exactly what a technician may be working on if he/she is unfamiliar with the system. Guesswork is virtually eliminated.

The ERFDADS system, based on SPARC 2 Workstations, received data from original DEC PDP 11/23 that was a form of decimal weighted binary code. The Dataloggers provide this data but only in comma delineated ASCII or pure engineering units. This presented a requirement to translate the Datalogger output to a form recognizable to ERFDADS. It was decided to dedicate a personal computer to this task, effectively a translator/server which Jerry Dudley, our software guru, dubbed the DataLink.

The new architecture of the digital processing system at the MDTS sensor end provided backups for both dialup and ERFDADS environments, so we decided to port this additional ERFDAD link directly to this i486 based DataLink and figure out a way to utilize this backup automatically. Communications would be handled by Campbell short haul modems at the met shelter/datalogger end and the interface to the ERFDADS Sparc II server, located in the Technical Support Center. The personal computer would be installed at this end as well, isolating it from the met shelter and eliminating this load from the MDTS shelter UPS.

As the company was going in the direction of a Microsoft 32 bit standard, we decided on Windows NT as the software platform for the data translator. Jerry was given carte blanche to develop and test the DataLink software and hardware. A virtual simulator was first developed to aid in the fabrication and operational verification of the translation code. This simulator was driven by data taken by one of the CR10 Dataloggers already installed and running (but not officially "operable") in parallel with the DEC PDP 11/23. Providing "real time" data for testing would ensure (in theory) the software would work properly from the first install. Based on extensive run time testing with the simulator, the applications that were first written in Visual Basic were discovered to have a problem in this real time environment as a result of timing problems. Jerry re-wrote the code using Brained Delphi and these problems were solved.

It was decided that the DataLink could be used to provide a few enhancements to the system. As it was, two dataloggers were dedicated to this data link. Code was added to determine, based on sensor status, which sensor data from which train would be sent to ERFDADS. E.g., the PC would default to Train A sensors, but if the 60 meter wind speed sensor should fail, Train B 60 meter wind speed sensor would be selected for data input. If one communication link fails for a predetermined time, the backup line would be selected, and this prioritized sensor data monitoring scheme would be repeated for this line. All sensors are monitored continuously and the status is displayed on the PC screen. Error status from the sensors, as well as key operating system status is saved in a circular error status buffer. On screen status indicators are also provided to indicate proper operation of the individual communication links. It is planned to write new software that will include algorithms based on pre-determined "windows" that will defer data from a sensor that, while working properly, will take into account tower shadow and switch to the more "accurate" sensor.

As mentioned earlier, if ERFDADS should be down, the requirement to obtain Tech Spec meteorological data was fulfilled by an operator taking a trip to the MDTS shelter and obtaining data locally. This option is still available, but with the additional phone line available, we provided a bit of dialup software for Operations in one of their personal computers. Their next choice now, assuming ERFDADS is faulting, is to select an icon on their screen and click. The personal computer modem dials up automatically and displays the appropriate data.

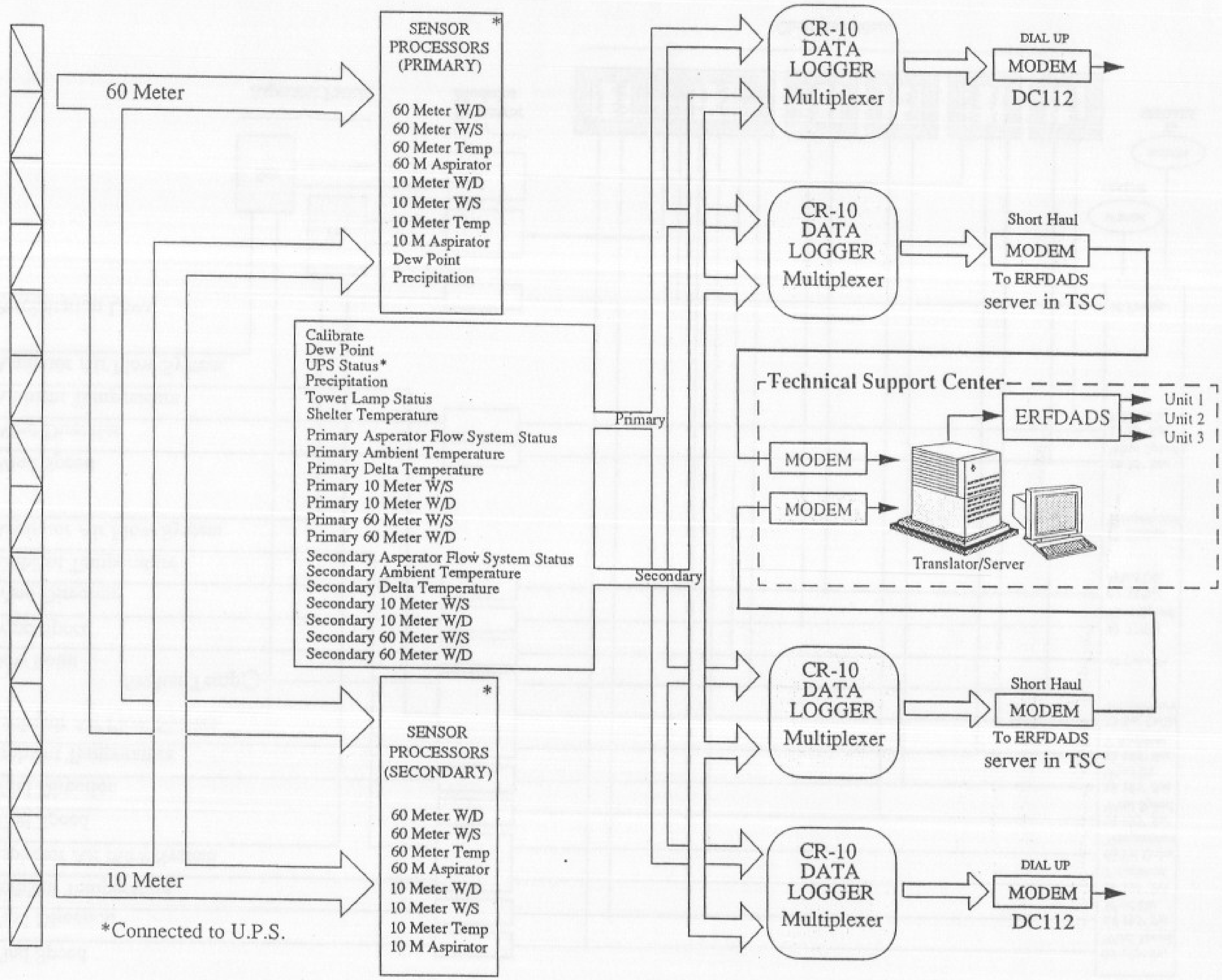
System "cutover" was virtually anticlimactic. The dataloggers had been running for weeks with the final version of software and acquired data had been compared to that of the old system to verify validity. Only a few wires had to be moved, specifically those that connected the autocalibration signals. Jerry had thoroughly tested the DataLink off line with his simulator, so this was the only somewhat questionable portion of the project. The personal computer was moved to the Technical Support Center and connected to the ERFDADS server with no problem, and immediately ERFDADS was back on line with MDTS. Only one parameter displayed a problem, which turned out to be only a scaling error, owing to the difference between ERFDADS and the MDTS. This was easily corrected and no changes have been necessary since that time.

SUMMARY

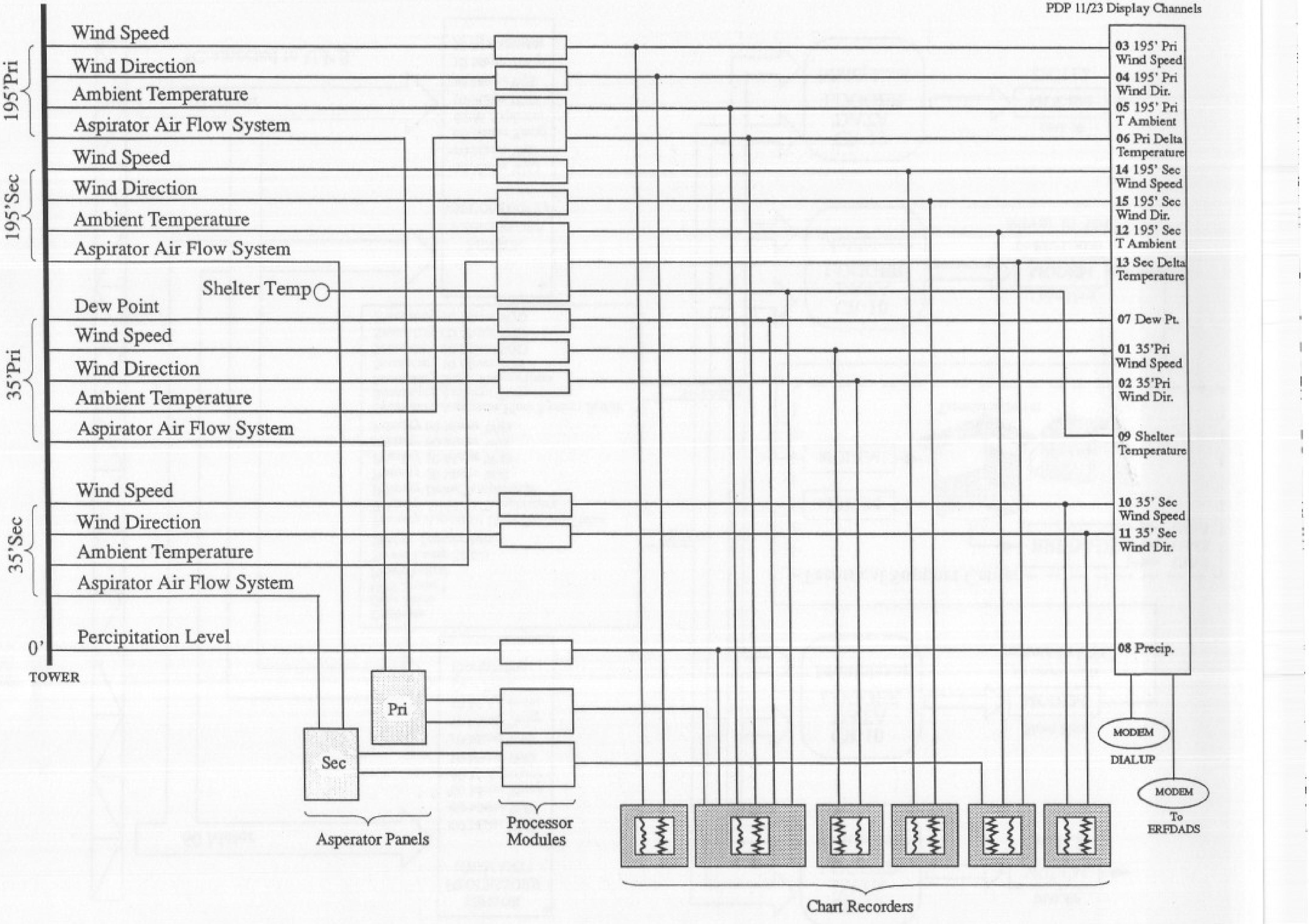
The PaloVerde MDTS has been operating, in it's new configuration, since December, 1995. To date there have been no instances of data loss, and total data retrieval is an accepted fact. This system has provided the following enhancements over and above the old system:

Backup system for Dial up data
Backup system for ERFDADS data
Intelligent interface to ERFDADS
Additional method for Operations to obtain data
Reduction of maintenance
Uninterruptable Power
Total control of software for future modification or enhancement
Improved and easy to use design documentation
Reliable communications
No reliance on outside contractors
Close to 100% data recovery
Happy meteorologist

In the current business and economic environment it is no longer possible to spend large sums of money to upgrade existing systems. The paradigm of "We must hire consultants to help us do our job" must be broken and onsite talent must be recognized and utilized. Palo Verde Nuclear Generating Station and its constituent departments are actively searching out and utilizing the varied talents of it's employees in all arenas of maintenance and design. This attitude and change from "business as usual" has reduced costs enormously and has provided some very novel and cost effective solutions. This team method provides individuals with ownership of the project and accentuates pride in the final product. The MDTS project, including Campbell Scientific Company factory training, was completed at a capitol cost of less than $22K. This money will be recovered in three months by the reduction in maintenance costs alone.



UPGRADED SYSTEM



ORIGINAL SYSTEM

MDTS DATA LINK
USER'S MANUAL
APPENDIX B
MAIN SCREEN

Time

	A	B
Hours:	23	23
Minutes:	07	07
Seconds:	11	11

Timing

Datalogger A | Datalogger B | Data Output

Wind Speed {mph}

	A	B
Primary 10 meter:	2.42	2.49
Redundant 10 meter:	2.50	2.48
Primary 60 meter:	2.71	2.75
Redundant 60 meter:	2.73	2.74

Wind Direction {degrees}

	A	B
Primary 10 meter:	12.1	12.3
Redundant 10 meter:	11.9	12.2
Primary 60 meter:	12.0	12.1
Redundant 60 meter:	11.9	12.1

Status

10m Pri. Asp.	A	B
10m Red. Asp.	A	B
60m Pri. Asp.	A	B
60m Red. Asp.	A	B
Tower Light	A	B
UPS Fail	A	B
Pri. In Cal.	A	B
Red. In Cal.	A	B

Temperature {degrees F}

	A	B
Primary Ambient:	79.1	80.2
Redundant Ambient:	80.1	80.0
Primary Delta:	1.2	1.2
Redundant Delta :	1.1	1.1
Shelter:	75.2	75.1
Dew Point:	27.3	27.1

Voltage {vdc}

	A	B
Battery:	12.3	12.5

Commands

Datalogger Control

Current Datalogger: A

- o Automatic Switchover
- o Manual [A] [B]

[Data Retrieval]

[Quit]

INTRODUCTION

During 1995, Palo Verde made an important decision to replace the meteorological data collection system. The two major site applications are associated with Emergency Planning and routine dose determination. Significant operational deficiencies dictated improvements that had been requested for over three years. Changes were dramatic; simplifying yet improving the system dramatically.

HISTORY

Palo Verde got somewhat serious about meteorology during plant operations in December 1984 when fuel was loaded in Unit 1. The system at that time was inadequate, having only a poorly operating set of three chart recorders: 10- and 60-meter winds and a multipoint for temperature and precipitation information. By November 1985, the system had been upgraded to include a dual sensor tower with a microprocessor to capture and temporarily store the data. Additionally, data was written to a line printer and inked on a redundant set of analog charts at the tower. Digital acquisition was possible only via modem communications. Only the most recent 96 hours was stored and some situations made that unretrievable. A contractor performed acquisition and processing through to the Regulatory Guide 1.21 Effluent - Dose report. By 1989, Palo Verde had developed an in-house capability to perform this work. Site layout and location of the meteorological tower are shown in Figure 1.

This system performed reasonably well or at least seemed to until the early 90's. As designed,only data from the primary sensors were available for use. The redundant (or secondary) sensors functioned only to verify the primary set under normal operations. Figure 2 shows the vertical profile (typical of both levels) of wind sensor extension and orientation.

Overrides (ability to reject any or all sensor measurements) were available should a failure occur or during calibrations. However, with time, it seemed as though the validation process began rejecting ever more data. Rejection examples are shown in Figures 3 and 4.

Wind selection problems are prominent in Figure 3. At 10 meters, improper rejections occur. The 60-meter speeds demonstrate incorrect "selection"; selection not really an option since, as stated above, only primary data can be presented. During the 2400-hour, three 10-meter speeds were not validated. The presented speed of 4.5 miles/hour based on only one 15-minute value was revised to 7.4 miles/hour during the review. Note the 60-meter speeds. In this case, with no malfunction nor rejection, the redundant speed was not available for use, but was the most appropriate choice.

Typical direction concerns are evident in Figure 4. The orthogonally computed direction using all four valid directions shifts by 67 degrees -- 3 sectors. Three of four 60-meter speeds were also rejected in this figure. This resulted in a one category shift when corrected. Thus, as can be seen from these examples, hourly values may be presented, but too frequently they were based on less than four 15-minute values. During many weeks, as much as 15% of the hourly averages (all variables) was totally missing. That's four rejections per hour. Another part of this problem existed when a temperature was missing (possibly a rejection). This would cause the entire 15-minute data set to be ignored. Since it was easily observed that the data was biased/weakened by too many improper losses, some remedy was in order.

DISCUSSION

As is the case with most system analyses, several steps were taken to evaluate the means to a cure. Calibrations, performed in-house, were reviewed via an audit (July 1992). Also, an intense study of the data and processes was undertaken. The results of both indicated improvements to the calibration could and did help, but little could be done to reduce rejections using the old DEC microprocessor. That unit had too many limitations and insufficient interest could be generated for changing the software or upgrading the computer. A decision to dispense with the microprocessor ruled out any revisions to the code, in particular the statistics portion. Validation/rejection status is determined by the statistics and occurs when the dual comparability, calculated for each variable set every 15 minutes, exceeds the pre-set thresholds. This process is shown later.

By late 1994, with "as-found" data recovery still poor (see Figure 5) and the microprocessor 10 years old, it was decided to replace it and the chart recorders with data loggers. Also, since Palo Verde has no true backup meteorological system, it was further decided to incorporate the dual sensor setup into our new operation in a manner to achieve highest accuracy and recovery rates.

Prior to logger installation, data reviews were conducted using information available on the line printer output. Nowhere else were the statistical calculations presented. Figures 6 and 7 describe the technique for deciding whether particular variables for any 15-minute period will be accepted. The statistical results are calculated every 15 minutes, but those results are printed only if a rejection occurs. Weekly reviews of the printer listings to determine validity of rejections were very time consuming -- about 12 to 15 hours to conduct and correct the data. On average, 40 hourly averages per week required correction.

ANALYSIS

Using presented statistics from the old system, a detailed study of 15-minute data provided insight into a valuable ability to discriminate appropriately between the sensors. The old system was manually set to produce statistics for every 15-minute data set regardless of rejection status. Two separate periods of approximately four weeks each were used -- one during the fall of 1994 and one during the spring of 1995. Applying this tower data analysis to new system (logger) data results allows a quicker, more efficient daily process, generally about 20 minutes per day for acquisition and review.

With a more limited, but sufficient, statistical presentation, the technique allows on-line data selection. As statistics (averages and standard deviations) are displayed during review, values are chosen from the primary or redundant sets to represent the period average. Thus far, this selection process may involve fewer than ten variables per day. This is subsequent to a software selection methodology that is very conservative and contains pre-determined threshold comparison values for each variable for each of 36 sectors. These sectors are centered on 5-degrees, 15-degrees, etc. North boundaries are 355-degrees to 005-degrees. Only those values exceeding the programmed limits remain for a meteorologist's selection.

Examples of the analysis using complete statistical data from past operations and routine rejections over several years showed some interesting results. Data were segregated into 10-degree groupings based on both primary and redundant readings. Results are not unexpected. It is understood that individual differences could exist between sensors, but similar results occurred at both levels. Only 10-meter information is presented here.

Figure 8 displays bias differences in average directions and average sigma-thetas for the 36 ten degree sectors. Because direction sensors are both located on the inboard end of the arms, interferences are more difficult to interpret. However, the primary boom extends three feet further from the tower, probably decreasing impacts from upwind equipment, especially the tower. Basically, directions are nearly equivalent for all but a few areas during very light speed conditions. Sigma-theta differences are grouped and data shows larger sigmas generally occur with impeded flow.

Speed average differences more clearly display the effect of tower and platform interference (Figure 9). Obvious biases exist with northerly component flows. The larger average difference of north-northeast is not mirrored to the north-northwest, perhaps because of the redundant speed sensor's proximity to the tower apparatus. In fact, primary speeds associated with north-northeast directions are frequently double those of the redundant sensors. The latter equipment is obviously more impacted by the tower. Speed differences are relatively minor for directions east clockwise through west-northwest.

Another display of speed differences relative to compass values is shown in Figure 10. Redundant speeds were subtracted from primary values. Percents of positive, negative and equal results were plotted for each of the 36 sectors. Equivalence percentages are highest to the southeast and west-northwest, but do not strongly dominate in those areas. Assuming nearly identical equipment, factors affecting speeds from these two directions must be similar.

Definite redundant speed dominance occurs to speed percentages of the north-northwest and east directions. Though higher redundant speeds of easterly flow comprise 60% of all east winds, averages are only 0.1 mile/hour greater than primary ones. Compared to other directions, east wind components are infrequent. As indicated in Figure 9, redundant speeds from the north-northwest show a large frequency of exceedance over primary speeds. This was expected as average differences are up to eight times greater than the east lobe values.

Percentages of primary speeds exceeding those of the redundant occur with northeast and southwest flow. Poor exposure for the redundant wind sensors would likely explain the high percentages of primary values associated with northeast winds. Somewhat similar exposures exist for the sensors with southwest flow, but for this region primary averages are only 0.1 mile/hour greater, though consistently so. Resultant primary averages during northeast direction cases are as much as 1.3 miles/hour greater.

Several acquisition and processing steps have been implemented for the new system operation to ensure high recovery and quality. Clock times are sent automatically to both loggers remotely from the acquisition computer (PC) to assure synchronization and is checked daily. Presently, an alarm message is received if either logger deviates from the PC time by more than 30 seconds. On the basis of findings from the review of past statistics, code was developed to provide an automated quality check on logger health, similar to a check-sum. Subsequent to acquisition, data from the two loggers are compared -- both loggers store collected information from both systems. This step provides loggers' signatures, UPS voltages and performs a software comparison of their data. Included in the download are daily electronic calibration values that are referenced against the semi-annual master calibration values for possible excessive drift. Figure 11 shows the results of one day's acquisition. Variables presentation during this step appear only if logger differences exceed two degrees for direction data and 0.5 for any other data type.

If inspection of this information exhibits no operational grief, i.e. the loggers are virtually identical, processing continues with one logger's data file. Each logger's signature must be exactly the same every day to assure its operational integrity and transmission quality. UPS voltages are printed as a check on system power.

There are two final steps to complete daily activities. First of these is an on-line screen display of all 15-minute data sets (primary and redundant) which were flagged for further inspection. Only data that did not pass the code thresholds, developed from the earlier study, appears during this step. Figure 12 is an example of this display. Data for the period of a flagged sensor is flanked by the adjacent 15-minute periods allowing a better picture of conditions. Again, based on knowledge from the earlier study, the meteorologist can select between primary and redundant values or declare the point missing if thought to be of questionable worth. The final step prints the day's data, including calibration checks and status values, and appends the hourly values to a monthly file.

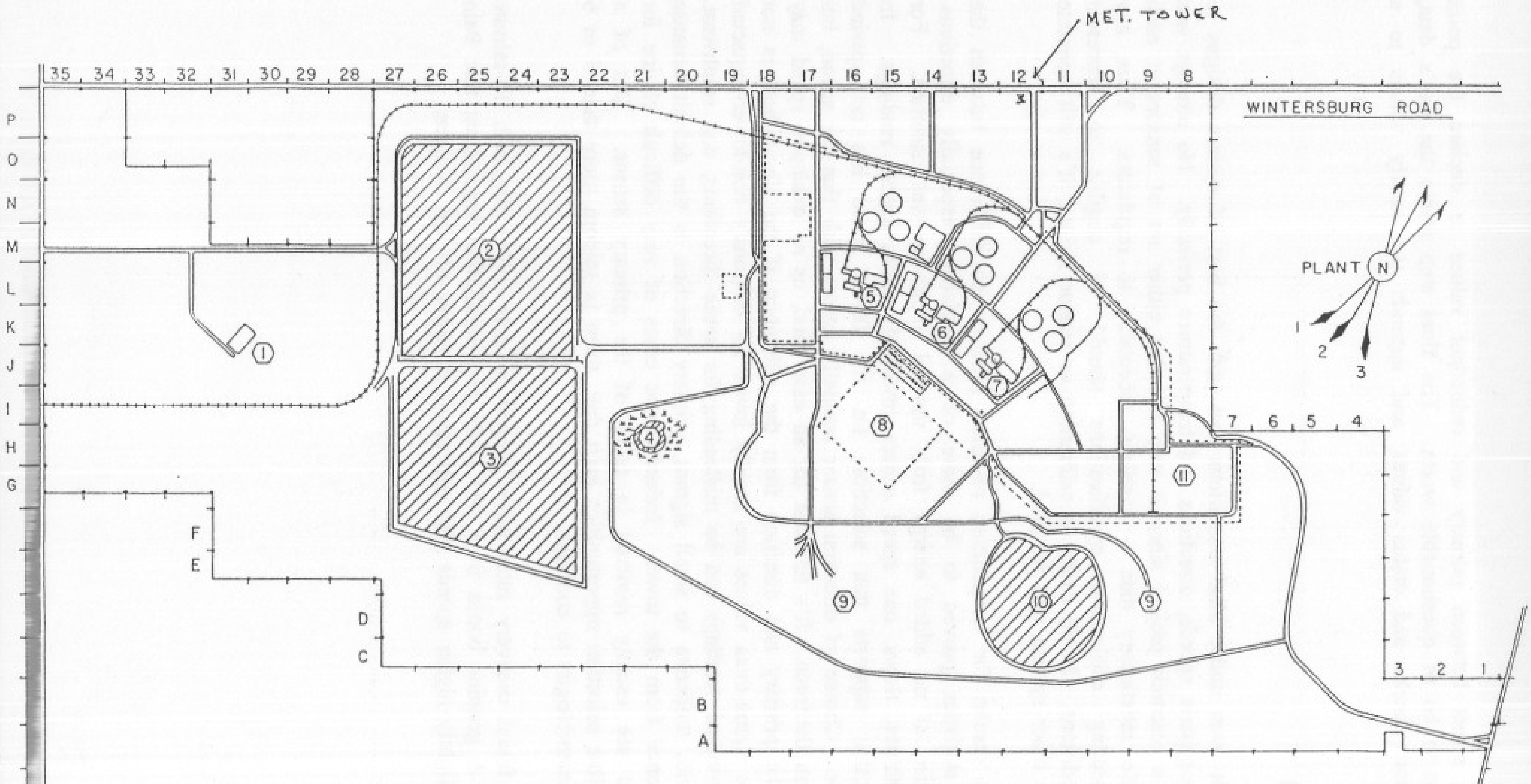
CONCLUSION

It's difficult even under ideal conditions and with the best of system designs to truly measure atmospheric speeds, directions and temperatures perfectly. No attempt was made to conduct a research project since it was felt that either set of sensors at each level could provide satisfactory data -- certainly acceptable to regulators. Thus, any tower sensor meeting calibration specifications should be eligible to represent meteorological conditions. In all cases of calibration or sensor failure, it's still operable counterpart on the other system will be used.

Comparison results for temperature revealed little or no difference between the sensors. Wind statistics proved to be more of a challenge, especially directions. However, a premise of no added energy from upwind apparatus was assumed. For northeast and northwest flows, one speed sensor invariably gives higher readings. In those cases, direction supports that selection, i.e. the faster speed has no upwind obstruction to flow. Choice of direction sensor normally agrees with that for speed, but that may depend on the force. It's felt that for an east wind, as an example, speed may be chosen from the primary and direction from the redundant if the sigma-theta is not too large. Average sigma-theta values are usually lower for obviously non-tower-impacted directions, but individual readings can be misleading for some directions, e.g. southwest. For such cases, with moderate to small sigmas, primary direction is the default because of its greater distance from the tower. Indeed, most cases of very difficult choice for direction or speed are usually resolved in favor of the primary sensor. Out of a potential 576 possible selection opportunities each day, there is seldom more than 5 or 6 per day for the meteorologist to consider.

Overall, as-found recovery rates have jumped to near 100% for both 15-minute and hourly data. A genuine bonus from this study and installation has shown that Palo Verde will have slightly higher speeds that will result in lower off-site dosages.

SITE OVERVIEW WITH J-HOOK AND EVAPORATION PONDS	DATE: ______ TIME:	REP #:	SURVEY #:



1	A.P.S. FIRING RANGE	7	UNIT ONE COMPLEX
2	EVAPORATION POND # 1	8	SWITCH YARD
3	EVAPORATION POND # 2	9	LANDFILL AREA
4	J-HOOK POND	10	MAKE-UP RESERVOIR
5	UNIT THREE COMPLEX	11	WATER RECLAMATION FACILITY
6	UNIT TWO COMPLEX		EACH GRIDDED SQUARE = 10 ACRES

FIG. 1

SURVEYOR:	REVIEWED BY: DATE:	INST. TYPE: S/N: CAL DUE:			

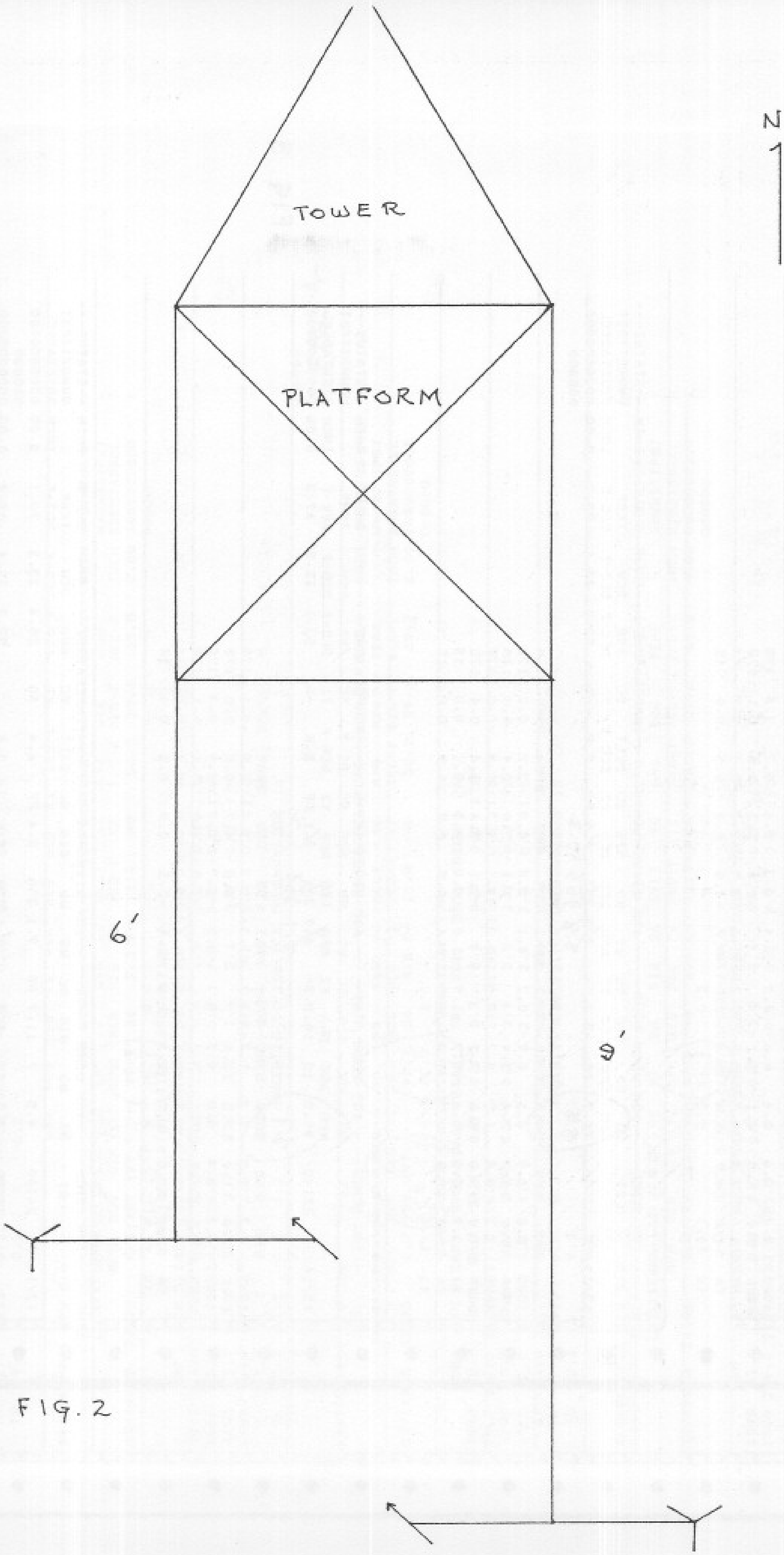


FIG. 2

*****ANPP01 REV 5.0 6.9

DATE	TIME LST	10M WIND WS MPH	WD DEG	SIG DEG	SC YZ	60M WIND WS MPH	WD DEG	SIG DEG	SC YZ	TEMPERATURE DELT DEG-F	SC YZ	AMB DEG-F	DEW DEG-F	SHELT TEMP DEG-F	RAIN INCH	STATUS WWWWDTTPST SDSDTADRCL
12/14/95	23:15	99.9 8.7	23	2.7	F-	8.8	5	4.1	EE	4.0	-G	54.2	34.3	69.9	0.00	0000000000 000000

VALIDITY STATISTICS INFORMATION

	SAM	SBM	SASD	SBSD	SAA3	SBA3	DB	DSD	DCOM	DSKW	N
10WS	8.7	5.4	0.5	0.8	0.3	-0.2	3.3	0.8	3.4	-0.0	178
10WD	23.0	23.0	2.7	3.9			-0.8	2.0	2.1	0.4	178
60WS	8.8	8.6	0.4	0.6	0.2	-1.4	0.3	0.6	0.7	1.5	178
60WD	5.0	6.0	4.1	5.1			-1.4	3.3	3.6	0.1	178
DT	4.0	3.9	0.5	0.5	0.3	-0.1	0.1	0.0	0.1	0.0	14
TA	54.2	54.7	0.4	0.4	-0.7	-0.7	-0.5	0.0	0.5	0.0	15
TD	34.3		0.2		-0.5						

*****ANPP01 REV 5.0

DATE	TIME LST	10M WIND WS MPH	WD DEG	SIG DEG	SC YZ	60M WIND WS MPH	WD DEG	SIG DEG	SC YZ	TEMPERATURE DELT DEG-F	SC YZ	AMB DEG-F	DEW DEG-F	SHELT TEMP DEG-F	RAIN INCH	STATUS WWWWDTTPST SDSDTADRCL
12/14/95	23:30	99.9 8.8	18	2.4	F-	7.7 8.8	353 355	8.0 7.2	DD	5.9	-G	52.3	33.4	70.0	0.00	0000000000 000000

VALIDITY STATISTICS INFORMATION

	SAM	SBM	SASD	SBSD	SAA3	SBA3	DB	DSD	DCOM	DSKW	N
10WS	8.8	6.0	0.5	0.9	0.3	0.1	2.8	0.8	2.9	0.2	178
10WD	18.0	16.0	2.4	3.4			1.3	2.0	2.4	0.2	178
60WS	7.7	8.8	1.2	0.3	0.0	-0.2	-1.1	1.2	1.6	-0.0	178
60WD	353.0	355.0	8.0	7.2			-2.1	2.6	3.4	0.4	178
DT	5.9	5.8	0.6	0.7	-1.9	-1.8	0.0	0.0	0.1	0.0	15
TA	52.3	52.8	0.7	0.6	1.8	1.4	-0.5	0.0	0.5	0.0	15
TD	33.4		0.3		1.2						

*****ANPP01 REV 5.0

DATE	TIME LST	10M WIND WS MPH	WD DEG	SIG DEG	SC YZ	60M WIND WS MPH	WD DEG	SIG DEG	SC YZ	TEMPERATURE DELT DEG-F	SC YZ	AMB DEG-F	DEW DEG-F	SHELT TEMP DEG-F	RAIN INCH	STATUS WWWWDTTPST SDSDTADRCL
12/14/95	23:45	99.9 7.7	12	10.5	D-	6.7 8.4	351 353	3.1 3.2	FF	5.8	-G	52.1	33.5	67.5	0.00	0000000000 000000

VALIDITY STATISTICS INFORMATION

	SAM	SBM	SASD	SBSD	SAA3	SBA3	DB	DSD	DCOM	DSKW	N
10WS	7.7	5.5	2.2	1.4	-1.3	-1.3	2.2	1.7	2.8	-0.1	178
10WD	12.0	11.0	10.5	11.4			0.8	4.7	4.8	0.0	178
60WS	6.7	8.4	0.8	0.3	0.7	-0.2	-1.7	0.9	1.9	0.4	178
60WD	351.0	353.0	3.1	3.2			-2.3	2.0	3.1	0.1	178
DT	5.8	5.8	0.9	0.9	1.0	0.6	-0.0	0.0	0.1	0.0	15
TA	52.1	52.8	1.2	1.1	-1.1	-0.4	-0.5	0.0	0.5	0.0	14
TD	33.5		0.6		-0.5						

*****ANPP01 REV 5.0

DATE	TIME LST	10M WIND WS MPH	WD DEG	SIG DEG	SC YZ	60M WIND WS MPH	WD DEG	SIG DEG	SC YZ	TEMPERATURE DELT DEG-F	SC YZ	AMB DEG-F	DEW DEG-F	SHELT TEMP DEG-F	RAIN INCH	STATUS WWWWDTTPST SDSDTADRCL
12/14/95	24:00	4.5	7	11.7	DD	7.1	350	3.4	FF	6.4	AG	50.4	32.3	70.1	0.00	0000000000 000000
	24:00	4.5 7.4	15	6.8		7.6 8.3	354	4.6		5.6		52.3	33.4	69.4	0.00	0000000000

*****ANPP01 REV 5.0

DATE	TIME LST	10M WIND WS MPH	WD DEG	SIG DEG	SC YZ	60M WIND WS MPH	WD DEG	SIG DEG	SC YZ	TEMPERATURE DELT DEG-F	SC YZ	AMB DEG-F	DEW DEG-F	SHELT TEMP DEG-F	RAIN INCH	STATUS WWWWDTTPST SDSDTADRCL
12/15/95	00:15	6.0	19	4.2	EE	6.9	350	7.9	DD	5.1	BG	51.8	33.4	70.1	0.00	0000000000 000000

*****ANPP01 REV 5.0

DATE	TIME LST	10M WIND WS MPH	WD DEG	SIG DEG	SC YZ	60M WIND WS MPH	WD DEG	SIG DEG	SC YZ	TEMPERATURE DELT DEG-F	SC YZ	AMB DEG-F	DEW DEG-F	SHELT TEMP DEG-F	RAIN INCH	STATUS WWWWDTTPST SDSDTADRCL
12/15/95	00:30	99.9 7.3	13	2.4	F-	9.2	4	7.5	EE	5.1	-G	51.4	33.5	70.1	0.00	0000000000 000000

VALIDITY STATISTICS INFORMATION

	SAM	SBM	SASD	SBSD	SAA3	SBA3	DB	DSD	DCOM	DSKW	N

FIG. 3

For this discussion, the "designated sensor" is sensor "A" or primary sensor. Sensor "B" is the redundant or backup sensor which is used in validating the value of sensor "A".

The rationale for using the comparability is as follows:

> The measured comparability of two redundant sensing systems can be related to the designed (or permitted) accuracy of the two individual systems.

The random errors to two independent (redundant) sensing systems are combined following the method of combining random errors in components of a system. The RMS (root mean square) of the two individual systems yields a value descriptive of the accuracy of determination involving both systems. Thus:

$$Accuracy_{dual\ system} = (Accuracy^2_{System\ A} + Accuracy^2_{System\ B})^{1/2}$$

The instrument comparability technique developed by NOAA used a similar expression for evaluating the comparability of two systems operating side by side:

$$DCOM = (DB^2 + DSD^2)^{1/2}$$

where:

DCOM = the Dual Comparability of the A and B sensing systems
DB = the Dual statistic of the difference between the A and B systems, or the ~~Basis~~ Bias
DSD = The Dual statistic of the Standard Deviation of the ~~basis~~ bias of the A and B systems.

FIG. 6

Table 8-5. Validity Statistics

Parameters

10 WS = 10-m wind speed (single and dual statistics)
10 WD = 10-m wind direction (single and dual statistics)
60 WS = 60-m wind speed (single and dual statistics)
60 WD = 60-m wind direction (single and dual statistics)
DT = Delta T (60m-10m) (single and dual statistics)
TA = Temperature (ambient) (single and dual statistics)
TD = Dewpoint (single statistics)

Statistics, Single (for each parameter)

SAM = Single statistic for system A, the mean
SBM = Single statistic for system B, the mean
SASD = Single statistic for system A, the standard deviation
SBSD = Single statistic for system B, the standard deviation
SAA3 = Single statistic for system A, the coefficient of the 3rd moment (skewness)
SBA3 = Single statistic for system B, the coefficient of the 3rd moment (skewness)

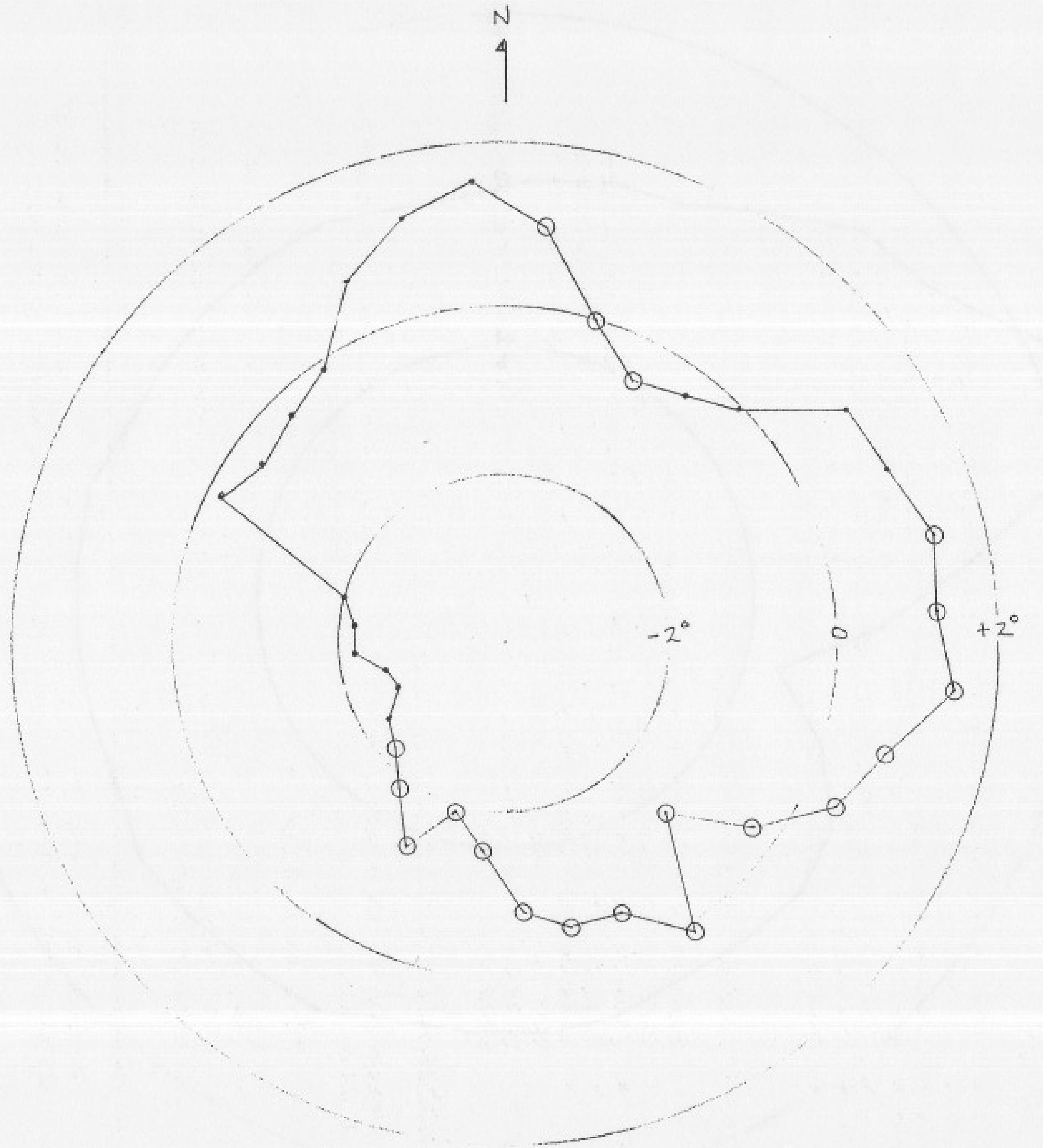
Statistics, Dual (for each parameter)

Each data point in a dual statistic is a difference of the sample value from system A minus the sample value from system B.

DB = Dual statistic, the bias (mean difference)
DSD = Dual statistic, the standard deviation (about the bias)
DCOM = Dual statistic, the comparability
DSKW = Dual statistic, the coefficient of skewness (of the 3rd moment about the bias)

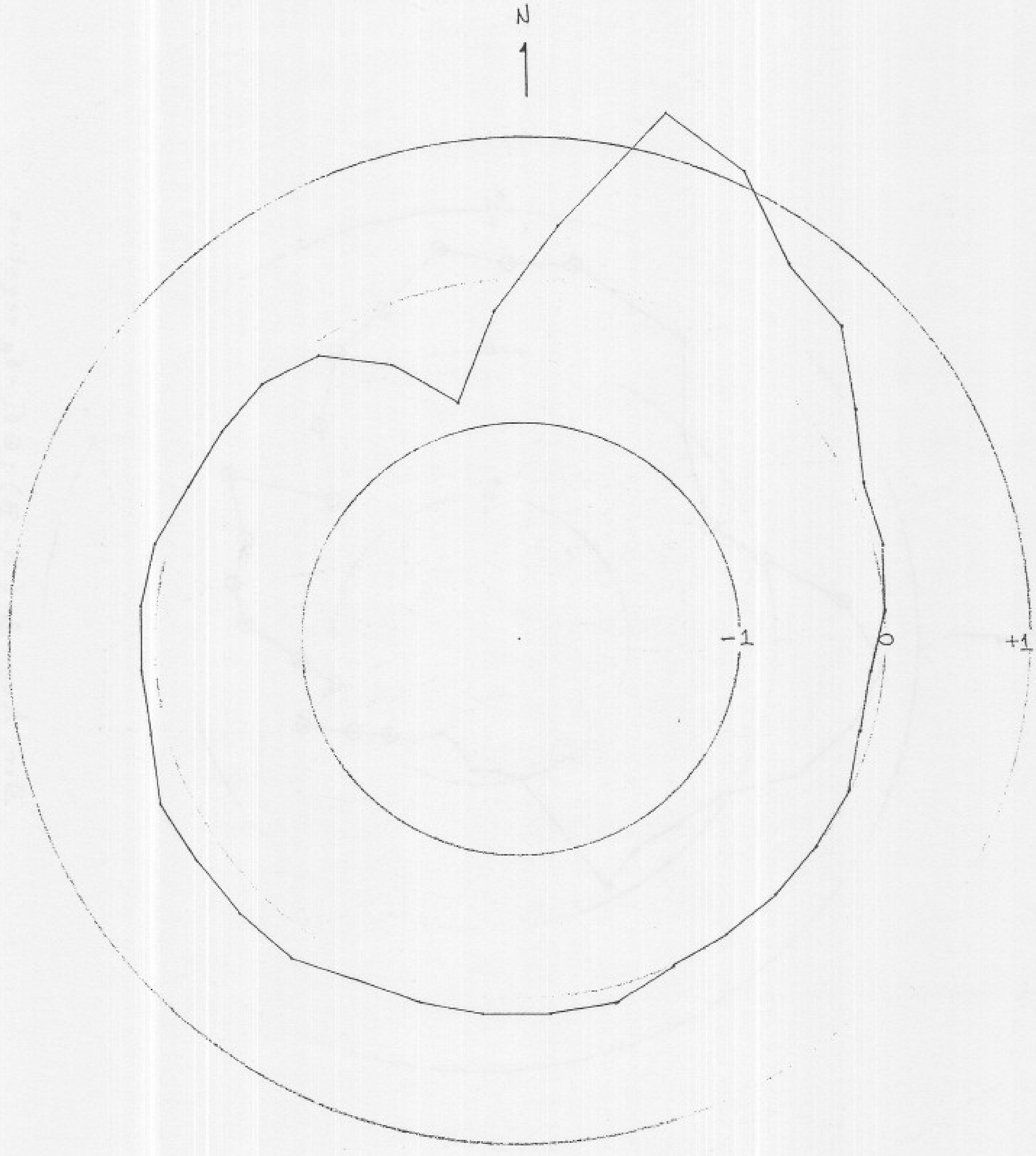
Note: System "A" = the "primary" system for a specific parameter
System "B" = the "backup" system for a given parameter

FIG. 7



Dir. Avg. Δ (A-B); ⊙ $\sigma_A - \sigma_B$ negative
· $\sigma_A - \sigma_B$ positive

FIG. 8



Speed Avg. Δ (A - B)

FIG. 9

FIG. 10

Percent of Speeds (A-B): negative (x……x)
equal (⊖—⊖)
positive (·———·)

```
ress any key to continue . . .

ommenced Logger File Matching
 Wd60a   parameters for 08:30 are > the matching criteria. 1 = 251.1 3= 247.9
 Wd60b   parameters for 08:30 are > the matching criteria. 1 = 268.8 3= 290.2
 Wd10b   parameters for 11:00 are > the matching criteria. 1 = 206.3 3= 203.1
 Wd60a   parameters for 12:30 are > the matching criteria. 1 = 181.8 3= 183.9
ompleted Logger File Matching
ogger 1 Signature : 1536 Battery voltage : 13.33
ogger 3 Signature : 4549 Battery voltage : 13.32
ress any key to continue . . .
```

FIG. 11

	SAM	SBM	SASD	SBSD
WS10	4.3	4.4	0.5	0.9
WD10	300.0	300.8	22.5	22.4
WS60	6.4	6.1	0.3	0.3
WD60	242.9	246.9	13.8	13.8
DT	1.2	1.3	0.4	0.4
TA	67.9	68.3	0.4	0.4
TD	44.7			

TIME 04:00 --STATUS-- WWWWDTTPST SDSDTADRCL 0010000000 BACKUP WWWWDT SDSDTA 000000

	SAM	SBM	SASD	SBSD
WS10	4.6	6.1	1.0	1.1
WD10	340.9	341.1	3.5	3.5
WS60	6.0	5.9	0.6	0.6
WD60	274.0	278.0	8.9	8.9
DT	2.3	2.5	0.4	0.4
TA	66.7	67.1	0.3	0.3
TD	44.0			

TIME 04:15 --STATUS-- WWWWDTTPST SDSDTADRCL 0010000000 BACKUP WWWWDT SDSDTA 000000

	SAM	SBM	SASD	SBSD
WS10	3.6	4.3	0.8	0.4
WD10	339.9	340.9	6.7	6.8
WS60	5.1	4.9	0.6	0.5
WD60	256.5	260.8	4.0	3.8
DT	3.3	3.4	0.5	0.5
TA	66.4	66.8	0.5	0.5
TD	43.8			

TIME 04:30 --STATUS-- WWWWDTTPST SDSDTADRCL 0010000000 BACKUP WWWWDT SDSDTA 000000

The WS10 parameter is being flagged
Do you want to chose 'A', 'B', or
M' for missing data ?

FIG. 12