CONFERENCE PROCE

16th Annual

ROCKY MOUNTAIN QUALITY CONFERENCE

Quality plus T.M.

Hyatt Regency Tech Center
Denver, Colorado

Tutorials/Seminars
Sunday, June 7, 1992

Two-Day Conference
June 8, 9, 1992

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The Conference Committee for the 16th Annual R.M.Q.C. would like to thank the 152 individuals who submitted applications for this year's R.M.Q.C. on June 8 and 9 and particularly the 50 speakers who made this year's program the best.

16th ROCKY MOUNTAIN QUALITY CONFERENCE Monday, June 8, 1992

7:00 to 8:00 **REGISTRATION AND EXHIBITS**– Convention lobby, rolls and coffee served
8:00 to 8:45 **WELCOME** – Joseph Tunner, Conference Chairman
KEYNOTE ADDRESS – Charles R. Eisele - Senior Assistant Vice President - Management Systems
Union Pacific Railroad

Break	Services	Quality Improvement	Statistics /Engineering	Teamwork	Training/Basic Skills
9:00 to 10:00	**Evaluating and Improving Services Processes** LOYD ESKILDSON Maricopa County Department of Health Services Page 2	**Quality Improvement - GEOPARDY!** DAN MUNSON Storage Technology Corporation Page 8	**The Application of SPC to Administrative Processes** ED LEWIS General Dynamics Page 9	**Self-Directed Work Teams - An Improvement Story** PAULA DAVIS International Quality Technologies Page 19	**Basic Skills and Quality: The Bottom Line** CHRIS KNEELAND Kneeland, Robinson, and VerStraeten Associates Page 25
Break					
10:30 to 11:30	Quality Function Deployment in the Service Sector DON BIESECKER Martin Marietta STEVE GELMAN Gelman & Associates Page 34	In the Nick of Time: Quality Value Banking JANET GRAY Value Concepts, Inc. Page 44	Modern Methods in Screening Technology GREGG K. HOBBS Hobbs Engineering Corporation Page 49	Modeling the Right Stuff, A Management Plan for Team Success ERLE LEWIS Leads Corporation Page 57	A Study of Work Environment Factors Associated with the Transfer of SPC Training to Shop-Floor Applications DANIEL J. FIELDS Eastern Michigan University Page 64
Break					
11:45 to 12:45	Systems Redesign in Action MARY ANN WERMERS Parkview Episcopal Medical Center Page 74	Behavioral Change: The Missing Element in the Quality Process ANN PINNEY Aubrey Daniels & Associates Page 84	Quality Attainment Through Concurrent Engineering Principles DR. SAMUEL KEENE IBM Page 89	Achieving Excellence by Combining Quality Related Education and Quality Improvement Teams DAVE DUMAS Micron Technology Page 108	Functions Required of Leadership for Successful Implementation of TQM Training GERARD R. TUTTLE, PH.D. U.S. Air Force Logistics Command Page 116

12:45 to 2:15 LUNCHEON – Service Sector Quality Award presented to Parkview Episcopal Medical Center, Mr. Michael D. Pugh, President/CEO

Break					
2:30 to 3:30	Healthcare Quality? What All Customers Should Know LYNN MARSHALL Marshall Consulting Page 128	Scaling the Baldrige Peaks ELIZABETH KEIM Innovative Systems Solutions Corporation Page 134	Managing Analytical Gaps in Industrial Research MARILYN MONDA AND EILEEN J. BEACHELL Consultants Page 140	Employee Participation: Getting and Keeping Employees Involved BETTY DUNCAN-LIZER Chem-Nuclear Geotech Page 153	Fun and Games in SPC Training: SPC Training Tools to Enhance Understanding JEFFERY LOWMASTER Crystal Specialities International Page 162
Break					
3:45 to 4:45	The Power of Vision LINDA S. MARKT Magic Valley Regional Medical Center Page 174	Group Technology is Quality's Best Friend WILLIAM F. HYDE AND BARRY LEVINE Brisch, Birn & Partners Page 183	SQC Application and Process Improvements to Human Dependent Processes WENDELL E. DAUGHERTY AND MARK E. TIMM McDonnell Douglas Page 196	A Case Study of TQM in Government CHARMAINE FARRAR Federal Highway Administration Page 203	Effective Data Presentation JAMES R. KING Consultant Page 211

16th ROCKY MOUNTAIN QUALITY CONFERENCE Tuesday, June 9, 1992

7:00 to 8:00 **EXHIBITS OPEN**– Convention lobby, rolls and coffee served
8:00 to 8:45 **WELCOME** – Wells Lange, Conference Chair-Elect
KEYNOTE ADDRESS – Robert V. Caine, Chairman American Society for Quality Control

Break	TQM	Computer Applications	Management/Leadership	Manufacturing Applications	Standards/Methods
9:00 to 10:00	**Total Quality Management: Prescription for Success** KENNETH L. NELSON AND JAMES P. FARRAR Motorola, Inc. Page 223	**Reporting Reliability Results Using Metrics and UNIX Software** JOHN A. CONTE DSC Communications Corporation Page 236	**Quality Versus Business Goals** BRYAN JAMES DAVIES British Telecommunications PLC Page 247	**A Successful ISO 9002 Registration Strategy** MICHAEL A. DEMMA Page 255	**Obtaining Goals via the "Quality Index" Matrix** DON FELDHAUS Consultant Page 258
Break					
10:30 to 11:30	**Total Quality Management: A Community College's Path to Continuous Improvement** DR. MARVIN LANE Lamar Community College Page 266	**A Top-Down Approach to Software Quality** DEAN LEFFINGWELL RELA, Inc. Page 304	**Communicating Quality is Everybody's Business** STEPHAN D. FRANK Metro Wastewater Reclamation District Page 311	**A Manufacturing Quality and Reliability Planning Process for New Product Development** JIMMY YANG Digital Equipment Company Page 320	**ISO 9000 Consultation: Who Needs It?** JAMES L. LAMPRECHT Consultant Page 334
Break					
11:45 to 12:45	**Executive Buy-In for Total Quality Management** WILLIAM D. KING Consultant Page 345	**Becoming More Responsive to the Customer** LYNN ST. CYR SHERICK IBM Page 354	**It All Depends, or Abuses and Misuses of Management by Facts** THOMAS A. SCRIPPS Quality Improvement Systems Page 355	**Manufacturing Measures for World Class Companies** CRAIG A. PIEPMEIER McDonnell Douglas Space Systems Page 373	**Getting Operations to Really Use SPC; MCPs Can Help** WAYNE E. ZIRK AND ROBERT D. FOSTER Union Carbide Corporation Page 382

12:45 to 2:15 LUNCHEON – Manufucturing Sector Quality Award presented to XEL Communications, William J. Sanko, President

Break					
2:30 to 3:30	**Performance Appraisal and Total Quality Management** GEORGE P. ECKES Storage Technology Corporation Page 389	**Software Kinetics** GENE MILUK Denver Metrics Group, Inc. Page 397	**Realizing a Dream: Integrating Quality into Day-to-Day Activities** LORI L. SILVERMAN Partners for Quality Page 407	**Quality Assurance in the Design of "Design Content" in Manufacturing Courses for Seeking ABET Approval** HAMID KHAN Ball State University Page 416	**Partnering for Quality** KAREN S. BECKER Micro Motion, Inc. Page 424
Break					
3:45 to 4:45	**The Zen of TQM** LARRY D. WASHBURN Consultant Page 434	**Quality Through Continuous Process Improvement** FRANK SANTARELLI IBM Page 445	**A Global Perspective of Quality** LLOYD A. CASEY Storage Technology Corporation Page 455	**Short-Run SPC - A Simple Approach** JIM PARKER Woodward Governor Company Page 462	**Quality Costs for Improvement** SUSAN H. TALL The Carmel Group Page 473

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1992 ROCKY MOUNTAIN QUALITY CONFERENCE

Reporting Reliability Results Using QMP Metrics and UNIX® Software

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1. Introduction

A new method of reporting reliability results for circuit packs used in the telecommunications industry has been developed. The new method uses QMP metrics and UNIX® [1] software tools to improve the process of reporting circuit pack return rates. The use of QMP (Quality Measurement Plan) metrics was originally proposed by Hoadley, in 1981, in the Bell System Technical Journal[2] for the purpose of reporting quality assurance audit results to Bell System management. In this application, QMP has been broadened to include the reporting of circuit pack reliability rates. The method described is applicable to a wide range of quality and reliability assessment problems.

This new method was made possible by using four UNIX software tools including: a C language program to compute the QMP metrics, ORACLE™ [3] relational database system software to process the large amounts of data, Documenter's Workbench™ [4] software to produce the reporting graphics, and a UNIX shell program to create a source file for subsequent processing by Documenter's Workbench software. Note that each of these software tools was first used in this application on a personal computer with an MS-DOS™ [5] operating system and subsequently ported to a multi-user computing environment. This paper is about software that many would associate with a UNIX operating environment but this software is also found in other computing environments.

This new method of reporting reliability results is a significant improvement over the previous method because:

- it produces a confidence interval in addition to a point estimate,
- it uses Bayesian statistics to consider five months of historical data in addition to the current month's data, and
- it reports the results in a graphic format instead of in a tabular format.

The method described in this paper has been successful in improving the information derived from circuit pack return data that was collected by an existing system. Using QMP metrics and UNIX software tools it was possible to report reliability results with more accuracy and better communication of the return rate phenomenon.

2. The Reliability Reporting Problem

DSC Communications Corporation is a leading designer, developer, and manufacturer of digital switching, transmission and private network systems for the worldwide telecommunications marketplace. In its fifteen year history, DSC has shipped more than a million telecommunications circuit packs. It is the responsibility of the Quality and Reliability Assurance organization to collect and report on the reliability of more than one thousand types of circuit packs.

Recently, one of DSC's largest customers asked a number of questions about the reliability of circuit packs shipped to its more than six hundred locations. The existing system was not capable of responding fully to the customer's detailed questions. Thus in the fall of 1991, this new method of reporting circuit pack reliability rates was created.

The basic problem is this: Given a universe of more than a million circuit packs consisting of about 1200 types, shipped to customers over a period of fifteen years, which circuit pack types are experiencing failure rates greater than predicted?

First note that given a universe of circuit packs in service, it is possible to compute the number of expected returns each month. The relevant reliability theory assumes (1) a constant failure rate for circuit packs in service, (2) properly manufactured circuit packs experience a higher failure rate only during the manufacturing **burn-in** process, and (3) circuit packs are removed from service, before a wear-out process begins. The wear-out process is predicted to begin after forty years of service.

Assuming a constant failure rate, the the expected number of failures per month can be computed as follows:

$$\textit{Expected Failures} = \textit{failure rate} \times \textit{hours per month} \times \textit{units in service}$$

The failure rate for telecommunications circuit packs is commonly expressed in FITs[6] or Failures In Time per one billion operation hours. The FIT rate for the example circuit pack is 9,627 predicted failures in one billion hours. There are an average of 730 operating hours per month and in our example circuit pack shown in Figure 1, there are 770 units in service in the month of July. Thus the **Expected Failures** in our example is:

$$\textit{Expected Failures} = \frac{9627}{1000000000} \times 730 \times 770 = 5.41$$

There is a difference between expected failures per month and expected returns per month. It is **expected** that about one third of the circuit packs returned each month will not be failures. These circuit packs, when tested at the manufacturer, will be diagnosed as **No Trouble Found** (NTF). In the process of restoring system service, sometimes more than one circuit pack may be replaced before the service is restored. Some of the replaced circuit packs are not defective, they were replaced as part of the trouble shooting process. Once service is restored, all of the circuit packs removed from service are returned to the manufacturer as defective. To account for this expected level of returns greater than the actual failures, the number of **Predicted Returns** is computed as follows:

$$\textit{Predicted Returns} = 1.5 \times \textit{Expected Failures} = 1.5 \times 5.41 = 8.12$$

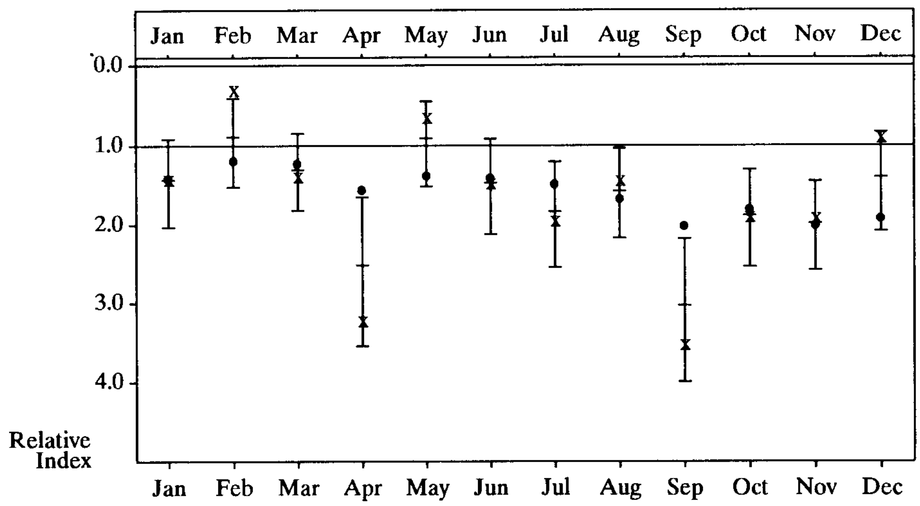
Now that the number of expected returns has been computed, a comparison to the actual number of returns can be made and the statistical significance can be assessed.

3. The Quality Measurement Plan (QMP)

The QMP metric was chosen as a reliability assessment metric because (1) it is a powerful estimate of true population quality, (2) it uses historical data, (3) it is known within the telecommunications industry, (4) it provides a confidence interval about the estimated true quality, and (5) when combined with a detailed graphical presentation, QMP conveys an excellent understanding of the return rate phenomenon.

DSC Circuit Pack Returns - ALL Customers

300-1019-966 DAC-1 FITs = 9627 MTBF = 103,875 hrs



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Packs Universe	593	596	674	674	704	764	770	778	831	842	835	822
Packs Returned	9	2	10	23	5	12	16	12	31	17	17	8
Pred Returns	6.25	6.28	7.11	7.11	7.42	8.05	8.12	8.20	8.76	8.88	8.80	8.67
Current Index	1.44	.32	1.41	3.24	.67	1.49	1.97	1.46	3.54	1.92	1.93	.92
Best Measure	1.43	.89	1.30	2.52	.91	1.47	1.83	1.57	3.03	1.88	1.98	1.40
Process Average	1.43	1.20	1.24	1.57	1.39	1.42	1.50	1.68	2.03	1.82	2.02	1.93
5th Percentile	.92	.41	.85	1.65	.45	.92	1.20	1.04	2.18	1.30	1.45	.83
95th Percentile	2.03	1.52	1.82	3.54	1.51	2.12	2.55	2.17	3.99	2.54	2.58	2.08

Figure 1. QMP Trend Chart using representative rather than actual data

In the example QMP chart given in Figure 1, a horizontal box has been drawn around the twelve variables that will be used for the July QMP computation. More specifically, those twelve variables are the **Packs Returned** in the months of February through July and the **Predicted Returns** in the months of February through July. The QMP computation function will return the five values in the vertical box - the **Current Index**, **Best Measure**, **Process Average**, **5th Percentile** and **95th Percentile** for July.

The interpretations that should be made from the July computation are:

1. The **Current Index** of the July data is 1.97 times predicted. The **Current Index** is the ratio of the **Packs Returned** in July and the **Predicted Returns** in July (16 / 8.12 = 1.97). This is a point estimate based on the actual returns and predicted returns for a single month of data. The **Current Index** is plotted on the graph as a "x".

2. The **Process Average** for July is computed using July's current index and five months of previous current indexes. This value is approximately the six month weighted ratio of **Actual Returns** and **Predicted Returns**. The approximation is due to the statistical preciseness with which Hoadley[2] chose to make this computation. The **Process Average** is plotted on the graph as a "•".

3. The **Best Measure** of the return rate for this circuit pack is 1.83 times worse than the predicted rate. This is Hoadley's **best** estimate of the **true** but unknown return rate ratio estimated on six months of data. This value always falls between the **Current Index** and the **Process Average**. It is closer to the **Process Average** when the process displays stability and closer to the **Current Index** when the process exhibits instability. The **Best Measure** is plotted on the graph as a "−".

4. The **5th** and **95th** percentiles represent the bounds of the 90% confidence interval. For the July computation these values range between 1.20 and 2.55 times worse than the predicted rate. The QMP statistician would say that he is 90% confident that the **true** return rate lies between 1.20 and 2.55 times that of the predicted. It would also be understood that this interval has a density function such that a higher probability exists that the true return rate is closer to the **Best Measure** than either the **5th** or **95th** percentile values.

5. Since the entire 90% confidence interval lies below the 1.0 relative index line, the QMP statistician is 95% confident that the **true** return rate is worse than predicted. Looking at the entire year in retrospect, the QMP statistician drew the same conclusion for the months of April, July, August, September, October, and November.

The purpose for the original development of QMP was to "reduce statistical errors relative to a prior method of analysis."[2] The purpose of this application of QMP to the reporting of circuit pack return rates is the same. The Quality Measurement Plan is completely described in a 1981 issue of the Bell System Technical Journal (BSTJ)[2] and in Bellcore Technical Reference TR-TSY-000438[7].

4. UNIX Software

The most important question one should ask about the software used for this problem solution is: "Is it available for my current computing environment?" My current computing environment is an Amdahl mainframe running a UNIX operating system. But this application was developed on a personal computer running MS-DOS and was subsequently ported to a multi-user, mainframe, corporate database environment. The difference between these two computing environments has more to do with the quantity and source of data for the application than the mechanics of the application. Most of the four software tools described are available for the MS-DOS, VAX[8], MVS[9] and UNIX computing environments.

Four software tools were used. They were a C language program to compute the QMP metrics, ORACLE relational database system software to process the large amounts of data, Documenter's Workbench software to produce the reporting graphics, and a UNIX shell program used to create a source file for subsequent processing by the Documenter's Workbench software. The uniqueness of this solution is in the integration of the four software packages. But more importantly, it was the graphics that made it possible to explain and popularize QMP metrics with those who eventually used them. That included everyone from the company president to our many customers who asked: "**Which of our circuit packs are experiencing return rates worse than predicted?**"

I owe much of what I understand about graphics to Cleveland from his book entitled, *The Elements of Graphing Data*.[10] This book contains an amazing collection of graphs created using Documenter's Workbench software. Note, however, that this book is not about computer graphics but is a scholarly book about the fundamentals of graphing data.

4.1 C Language

For most of the past twelve years that I have used QMP metrics, I have used object modules supplied by the former Bell System. The QMP metric was not meant to be proprietary. But, the documentation of the formulas is so frightful that organizations are inclined not to write the computer programs necessary to support it's implementation.

On my first occasion to use QMP without the benefit of a former Bell System supplied object module, I used QMPTREND[11] software. This MS-DOS software is an easy and painless introduction to QMP metrics. This software package does produce both tabular and graphic outputs. But compared to the graphics produced by Documenter's Workbench software, QMPTREND software's are grossly inadequate.

In order to move this application to a multi-user computing environment, it was necessary to write a C language version of the QMP metric function. Surprisingly, it took only two weeks for two of our staff members to write this program. The C language code listing for this function is beyond the scope of this paper. The author should be contacted for technical papers or shareware programs that might have been written about the QMP function after publication of this paper.

4.2 The ORACLE Relational Database

Database management systems (DBMS) are general purpose programs that dramatically reduce the time necessary to computerize an application. They allow you to enter, store, manipulate, and retrieve information in a database. ORACLE provides interactive access to databases using SQL*Plus[12] and provides easy ways to create printed reports or files.

A relational database is defined with two or more tables each related to one another with a common field. This particular application relied on two principle tables.

The **partfile** table contained information about each circuit pack type including:

part_num	part_desc	fit_rate

Figure 2. Record Description for Partfile Table

- **part_num** is the ten digit part number of each circuit pack type.
- **part_desc** is the fifteen-character part name of each circuit pack type.
- **fit_rate** is the failure rate expressed in FITs per billion hours.

The **pack_sum** table contained monthly summary information about each circuit pack universe under study including:

part_num	cust_gp	period	univ	rtns_exp	rtns_act	5-QMP_metrics

Figure 3. Record Description for Pack_sum Table

- **part_num** is the ten digit part number of each circuit pack type.
- **cust_gp** is the four-character customer group code of major customer groupings including "ALL " customers.
- **period** is the four character period identification of year and month (YYMM).
- **univ** is the number of circuit packs cumulative shipped to the field for this part number and customer grouping. This is somewhat of a liberal best guess of the **universe** of packs in service.
- **rtns_exp** is the number of predicted returns for this month and this customer grouping and part number.
- **rtns_act** is the number of actual returns from the field for this month for this customer grouping and part number.
- **5-QMP_metrics** are the five values returned from the QMP computation including current index (cindex), process average (procavg), best measure (bestmeas), 5th and 95th percentiles (percent5 and percent95).

Using Standard Query Language (SQL) on the ORACLE database, the value of each field in the database was output as either data for a Documenter's Workbench graphing program or as text used to title the graph. Provided in Appendix A is the SQL code to generate the title for the example graph. The output from this SQL script is given as Figure 4.

```
300-1019-966  DAC-1    FITs=  9627    MTBF=    103,875 hrs
```

Figure 4. Title Text for Sample Graph

Provided in Appendix B, is the SQL code to generate the data lines, for the example graph. One line of the output from this SQL script is given as Figure 5.

```
QMP(3001019966ALL ,9107,,770,8.12,16,1.97,1.50,1.83,1.20,2.55)
```

Figure 5. Data line used by Documenter's Workbench **grap** program

4.3 Documenter's Workbench Software

Documenter's Workbench software provides tools of unusual precision for sophisticated processing of text. The software package is the result of unbundling and repackaging the **nroff** and **troff** (pronounced N-roff and T-roff respectfully) commands of the System V release of UNIX (1983). Hereafter, I will use **troff** as a colloquial term for Documenter's Workbench software. My favorite remark about **troff** is "UNIX has always come with troff and friends { of troff }" in a book entitled *Life with UNIX - A Guide For Everyone*.[13] That book also notes that Bell Telephone Laboratories was the first user of a UNIX software package. That software package was **troff** used as a text processing package for its patent office in 1970. In the 1980's personal computer software introduced the what-you-see-is-what-you-get (WYSIWYG) interface to text processing. Those of us ardent **troffers** like to call this kind of software what-you-see-is-all-you-get software because by comparison "troff is extremely flexible, and experts can do amazing things with it."[13] A complete description of Documenter's Workbench software is available in two books written by Narain Gehani. The first book[14] has excellent documentation on processing text, tables, simple line drawn figures and equations. The second book[15] has probably the most extensive description of drawing graphs with Documenter's Workbench outside of Bell Labs.

Currently, only three companies, Elan Computer Group[16], Image Network[17], and SoftQuad[18], aggressively market **troff** for various operating systems including MVS, VMS, MS-DOS and UNIX. These software packages support various laser printers.

Version 2.0 of Documenter's Workbench software was released in 1986 with the significant addition of the **grap** command. **Grap** is a pre-processor language that produces input for the **troff** text processor. Most of the source code processed by **grap** is passed through unchanged, but statements between **.G1** and **.G2** are translated into commands that draw graphs.

The complete **troff** and **grap** source code for the graph in Figure 1 is given in Appendix C. The following examples of **troff** and **grap** code are provided to demonstrate the character and flexibility of Documenter's Workbench software.

4.3.1 Troff Code Lines of source code that begin with a "." (dot) are common **troff** format control lines. Lines of source code that do not begin with a **dot** are either text or pre-processor commands. A short introduction to a couple of these format control lines follows:

- **.ce** - (line 301) center the next line of text (line 302) between the left and right margin.
- **.sp** - (line 303) vertically space one line in the down direction.

4.3.2 Grap Code Beginning with the **.G1** (line 306) you will find the following examples of **grap** code:

- **frame ht 2.4 wid 4.6** - (line 307) defines the basic dimensions of the graph at 2.4 inches high and 4.6 inches wide.
- **coord x 0.50,12.50 y 0.1,-5** - (line 308) defines a graph with a coordinate system from 0.50 to 12.50 in the x direction and 0.1 to -5 in the y direction. Note that the rating periods (x-coordinate) are transformed from a notation of 9101, 9102, ..., 9111, 9112 to 1 to 12 (line 323). Setting the x coordinate system from 0.50 to 12.5 and plotting only values 1 to 12 allows a margin 0.50 units at the left and right of the the twelve months of data. Also note that quality charts are typically plotted so that **up** direction is the **improvement** direction.
- **"Relative" rjust at -0.2,-4.74** - (line 314) place the text **Relative** right justified at the coordinate position of -0.2 (x direction) and -4.74 (y direction). This equates to the lower left hand corner of the graph.

- **line from 0.50,-1.00 to 12.50,-1.00** - (line 321) draw a line from the coordinate pair 0.50,-1.00 to 12.50,-1.00. This is the horizontal line on the graph that identifies the standard quality level.
- **define QMP Z** - (line 322) defines the macro **QMP** between the letter **Z** and the next **Z** (line 338). Data passed to this macro in the form of Figure 5 will be processed by this macro. Such macro definition allows the passing of positional parameters designated "$1" through "$10".

If this coding seems particularly tedious, note that almost two months were consumed in efforts to create QMP graphic reports using Harvard Graphics[19] software in an MS-DOS computing environment. Those efforts were largely unsuccessful because the QMP graphic was not a standard business graphic and we were not able to print the supporting data with the precision desired.

4.4 UNIX Shell Program

A UNIX shell program was used to create a source file for subsequent processing by the Documenter's Workbench software. Appendix D provides a listing of the UNIX shell program to produce the example **troff** source file. In order for this method to work in an MS-DOS computing environment, you must have UNIX shell programming software on your MS-DOS computer. This type of software is available.[20]

The basic idea is to create a file named **chart.src** that is the source file to be processed by the Documenter's Workbench software. In the first two lines, two variables, **cust_id** and **pack_id** have been defined in the shell. These two variables will be passed to the SQL*Plus commands. The **cust_id** variable is also used as part of the title of the graph (line 404). The **echo** commands (lines 403, 404, 405, 406, 409, 410, and 414) put whatever is enclosed within the double quotes into the **chart.src** file. The **cat** commands (lines 408, 411, and 413) put the contents of the files **chart.txt**, **chart.dat**, and **chart.mac** into the file **chart.src**. The file **chart.txt** file was created with the SQL*Plus call (line 407) to the database table **partfile**. The file **chart.dat** file was created with the SQL*Plus call (line 412) to the database table **pack_sum**. The file **chart.mac** contains the charting macros written for the purpose of drawing the example graph. The last line in the script is the command that will **troff** the file **chart.src** and print the example graph on a laser printer. It consists of the pre-processor **grap** command, the **troff** command, and the **print_troff** command.

5. Conclusion

The result of this new method of reporting reliability data was a more accurate, descriptive, and useful reporting mechanism. It demonstrates a friendly use of sophisticated statistics and a graphic output from a multi-user computing environment. Using QMP metrics and UNIX software tools it was possible to report reliability results with more accuracy and a better communication of the return rate phenomenon to both management and customers.

6. Acknowledgements

I am grateful to John Bischoff, Vice President of Quality at DSC, and Phill Snow, Director of Reliability Assurance at DSC, for providing management support and encouragement for this new method of reporting reliability. I am grateful to the members of my Quality Action Team including Lorn Christal, Mike Gray, Halayn Hescock, Gary Tapper, Don Topper, and Robin Waggoner, for applying the principles of Quality Action that supported the successful implementation of this new method.

REFERENCES

1. UNIX is a registered trademark of AT&T.

2. Hoadley, Bruce. The Quality Measurement Plan (QMP), *Bell System Technical Journal,* Volume 60, No. 2, February 1981, pp. 215-273.

3. ORACLE is a registered trademark of Oracle Corporation.

4. Documenter's Workbench is a trademark of AT&T.

5. MS-DOS is a trademark of Microsoft Corporation.

6. Bell Communications Research, *Reliability Prediction Procedure for Electronic Equipment,* Technical Reference NWT-000332, Issue 3, Bellcore, Red Bank, NJ.

7. Bell Communications Research, *The Quality Measurement Plan (QMP)*, Technical Report TSY-000438, Bellcore, Red Bank, NJ.

8. VAX is a trademark of Digital Equipment Corporation.

9. MVS is a trademark of IBM Corporation.

10. Cleveland, William S., *The Elements of Graphing Data*, Wadsworth, Inc., 1985.

11. *QMPTREND Software*, Bell Communications Research, Inc., Phone 1-800-521-2373.

12. SQL*Plus is a registered trademark of Oracle Corporation.

13. Libes, Don and Ressler, Sandy. *LIFE WITH UNIX - A Guide For Everyone*. Prentice Hall, Englewood Cliffs, New Jersey, 1989.

14. Gehani, Narain. *Document Formatting and Typesetting on the UNIX® System*, Silicon Press, Summit, New Jersey, 1986.

15. Gehani, Narain and Lally, Steven. *Document Formatting and Typesetting on the UNIX® System Volume II grap, mv, ms & troff*, Silicon Press, Summit, New Jersey, 1988.

16. *Eroff™ Desktop Typesetting System*, Elan Computer Group, Inc., Mountain View, CA., Phone 415-964-2200.

17. *Xroff™*. Image Network, Mountain View, CA., Phone 415-967-0542.

18. *SoftQuad™ Publishing Software*, SoftQuad Inc., Toronto, Canada, Phone 416-239-4801.

19. *Harvard Graphics*, Software Publishing Corporation.

20. *MKS Toolkit*, Mortice Kern Systems Inc., Waterloo, Ontario, Canada, Phone 1-800-265-2797.

*Appendix A - ORACLE SQL*Plus code for generating the file chart.txt (xpack1.sql)*

```
spool chart.txt;
select substr(part_num,1,3), '-', substr(part_num,4,4), '-',
       substr(part_num,8,3), '    ', part_desc, '    ',
       'FITs=', fit_rate, '    ', 'MTBF=',
       to_char((1000000000/fit_rate),'9,999,999'), ' hrs'
       from partfile where part_num='&1';
```

*Appendix B - ORACLE SQL*Plus code for generating the file chart.dat (xpack2.sql)*

```
spool chart.dat;
select 'QMP(', part_num, cust_gp, ',', period, ',,',
              to_char(univ,'9999999'), ',',
              to_char(rtns_exp,'9999.99'), ',',
              to_char(rtns_act,'9999'), ',',
              to_char(nvl(cindex,0),'999.99'), ',',
              to_char(nvl(procavg,0),'99.99'), ',',
              to_char(nvl(bestmeas,0),'99.99'), ',',
              to_char(nvl(percent5,0),'99.99'), ',',
              to_char(nvl(percent95,0),'99.99'), ')',
          from pack_sum where part_num='&1' and cust_gp='&2'
          and period between 9100 and 9113
          order by period;
```

Appendix C - troff and grap Source Code for example graph

```
.ce
DSC Circuit Pack Returns - ALL Customers
.sp
.ce
300-1019-966   DAC-1     FITs=  9627    MTBF=    103,875 hrs
.G1
frame ht 2.4 wid 4.6
coord x 0.50,12.50 y 0.1,-5
ticks top out  0.02 at 1 "Jan", 2 "Feb", 3 "Mar", 4 "Apr", 5 "May", 6 "Jun"
ticks top out  0.02 at 7 "Jul", 8 "Aug", 9 "Sep", 10 "Oct", 11 "Nov", 12 "Dec"
ticks bot out  0.04 at 1 "Jan", 2 "Feb", 3 "Mar", 4 "Apr", 5 "May", 6 "Jun"
ticks bot out  0.04 at 7 "Jul", 8 "Aug", 9 "Sep", 10 "Oct", 11 "Nov", 12 "Dec"
ticks left out at 0 "0.0", -1 "1.0", -2 "2.0", -3 "3.0", -4 "4.0"
"Relative" rjust at -0.2,-4.74; "Index" rjust at -0.2, -5.00
"Packs Universe" ljust at -1.85,-6.00; "Packs Returned" ljust at -1.85,-6.50
"Pred Returns" ljust at -1.85,-6.75;  "Current Index" ljust at -1.85, -7.25
"Best Measure" ljust at -1.85, -7.50; "Process Average" ljust at -1.85, -7.75
"5th Percentile" ljust at -1.85, -8.25; "95th Percentile" ljust at -1.85, -8.50
line from 0.50,.7 to 12.50,.70   ;   line from 0.50,0 to 0.50,0.7
line from 0.50,0.00 to 12.50,0.00;   line from 12.50,0 to 12.50,.7
```

```
line from 0.50,-1.00 to 12.50,-1.00
define QMP Z
xc = $2 - 9100
boxwidth=.2; x1=xc-boxwidth/2; x2=xc+boxwidth/2
ci=-$7; lt=-$8; bm=-$9; p95=-$10; p5=-$11
if $7 <=5.0 then T "x" at (xc+0.010,-$7) T
if $8 <=5.0 then T "+" at (xc+0.010,-$8) T
if $11 > 5.0 then T p5 = -5.0 T
if $10 > 5.0 then T p95 = -5.0 T
if $9 > 5.0 then T bm = -5.0 T
line from (x1,p5) to (x2,p5); line from (x1,p95) to (x2,p95)
line from (xc,p5) to (xc,p95); line from (x1,bm) to (x2,bm)
"$4"  rjust at xc + 0.4 ,-6.00; "$6"  rjust at xc + 0.4 ,-6.50
"$5"  rjust at xc + 0.4 ,-6.75; "$7"  rjust at xc + 0.4 ,-7.25
"$9"  rjust at xc + 0.4 ,-7.50; "$8"  rjust at xc + 0.4 ,-7.75
"$10"  rjust at xc + 0.4 ,-8.25; "$11"  rjust at xc + 0.4 ,-8.50
if $10 > 5.00 then D "$10" at xc,-4.8 D
Z
QMP(3001019966ALL ,9101,,593,6.25,9,1.44,1.43,1.43,.92,2.03)
QMP(3001019966ALL ,9102,,596,6.28,2,.32,1.20,.89,.41,1.52)
QMP(3001019966ALL ,9103,,674,7.11,10,1.41,1.24,1.30,.85,1.82)
QMP(3001019966ALL ,9104,,674,7.11,23,3.24,1.57,2.52,1.65,3.54)
QMP(3001019966ALL ,9105,,704,7.42,5,.67,1.39,.91,.45,1.51)
QMP(3001019966ALL ,9106,,764,8.05,12,1.49,1.42,1.47,.92,2.12)
QMP(3001019966ALL ,9107,,770,8.12,16,1.97,1.50,1.83,1.20,2.55)
QMP(3001019966ALL ,9108,,778,8.20,12,1.46,1.68,1.57,1.04,2.17)
QMP(3001019966ALL ,9109,,831,8.76,31,3.54,2.03,3.03,2.18,3.99)
QMP(3001019966ALL ,9110,,842,8.88,17,1.92,1.82,1.88,1.30,2.54)
QMP(3001019966ALL ,9111,,835,8.80,17,1.93,2.02,1.98,1.45,2.58)
QMP(3001019966ALL ,9112,,822,8.67,8,.92,1.93,1.40,.83,2.08)
.G2
```

Appendix D - UNIX shell to produce sample graph

```
cust_id=ALL
part_id=3001019966
echo ".ce" > chart.src
echo "DSC Circuit Pack Returns - $cust_id Customers" >> chart.src
echo ".sp" >> chart.src
echo ".ce" >> chart.src
sqlplus -s userid/passwd @xpack1 $pack_id
cat chart.txt >> chart.src
echo ".sp" >> chart.src
echo ".G1" >> chart.src
cat chart.mac >> chart.src
sqlplus -s userid/passwd @xpack2 $pack_id $cust_id
cat chart.dat >> chart.src
echo ".G2" >> chart.src
grap chart.src | troff | print_troff
```
