when the ticketing agent operated the agent set) will be held for comparison with a keypunched card produced following a telephone call from the ticket agent to a voice recorder at the reservations office.

Question: What computer do you use? How long has it been used in this operation?

Answer: We plan to use the Remington Rand Univac, Model 1 File Computer, and at this date (March 10) the program debugging has progressed to the point where it is about 95 per cent complete. Agent set sales have been entered through prototype equipment into the particular Model 1 File Computer which will be installed in our New York Office this summer. All the transactions mentioned have been tested and have produced the results anticipated and related here.

Question: Is this system operational? If so, what is the operating reliability experience?

Answer: See answer immediately preceding. We are asking for a reliability exceeding 99.7 per cent of the scheduled operating time.

Question: What is the present state of the development of the system? What, if any, portions are in operation?

Answer: See answers immediately preceding.

Question: What steps do you take if there is an interruption between the agent's set and remote location?

Also, is the information contained by the central computer retained elsewhere for reference in the event of system failure?

Answer: The action to be taken will depend to some degree upon the particular circumstances, such as the duration of the interruption, the proximity of other agent sets and their operating condition, the nature of the interruption, etc. In general, a location dependent upon agent set service will use other communications facilities such as telephone and/or teletype when the agent set service is not available.

Each time that an agent set operation results in adjustment of the inventory, the computer produces a punched card record of the transaction (as stated in answer to previous question). This punched card record also contains a record of the entire inventory for the flight as it exists after the adjustment which produced the record. It is planned to process these records at fifteen-minute intervals on conventional punched card processing equipment so that it will be possible to revert to a completely manual system within a few minutes if necessary. This protection will be removed when experience proves that it is no longer necessary.

Question: What were some of the considerations that led you to choose a general purpose computer rather than a special purpose computer?

Answer: The answers to previous questions have partially answered this one. Perhaps the most important single consideration was recognition of the fact that we didn't really know *in sufficient detail* just what we wanted the computer to do. The electronic data-processing science and our need to apply it were developing at the same time. We had to get a program under way without being able to supply detailed specifications. It was apparent that it would take us several years to reach the point where we would know what to specify; it also was apparent that we would need the equipment by that time. We, therefore, decided to select as the central data processor, a general purpose computer which would meet the broad requirements of large capacity random-access storage and something faster than slow-speed processing. (We would like to have had a much faster data processor.) With this much behind us we could concentrate on the detailed specifications for the equipment which at that time appeared to be more special purpose; *i.e.*, the agent set and associated communications equipment. As it has turned out, the agent set and related equipment are a great deal more general purpose than any of us anticipated. Within the next decade there will be a tremendous increase in the use of these devices.

Question: What is the required up time per day for this system and what provisions are made for handling the load in the event of a major electronic or mechanical failure?

Answer: The required up time is twenty-two hours per day, seven days per week. As previously indicated, punched card records will be available to provide the basis for reverting to a manual system of control. The manual system would be comparable to our present system, modified only to fit the new type of record and to take advantage of then existing facilities.

Stock Transaction Records on the Datatron 205

A. H. PAYNE†

SEVERAL users of stock market transaction records maintain teams of ticker watchers to compile price files. Six to eight such teams are kept by wire services and some newspapers. Each of the two major odd-lot brokers and Teleregister Corporation, with its quotation board service, are among others who monitor the ticker visually. Not all of these cover more than one exchange but some do.

The use of a computer to monitor the ticker automatically was accomplished by Melpar for Standard and Poor's Corporation in order to compute their "Standard 500" indexes. Fig. 1 shows schematically the flow of information from the standard Western Union 6-channel ticker code through a converter to a punched paper tape which is suitable for input to the Datatron 205 computer. Examples of the paper tape involved are shown in Fig. 2. In Fig. 3 is shown the correspondence between ticker characters and digit-pairs within the computer. The 4000 words of main storage within the computer are used as diagrammed in Fig. 4. Outputs from the computer are the hourly indexes, daily small-group indexes, and price files for starting next day.

† Melpar, Inc., Boston, Mass.

Operating Speed

At maximum ticker speed the computer is occupied about 55 minutes of each hour, processing, computing indexes, printing rejected prices, and punching the price file periodically for safety. The level of market activity varies considerably and on less active days, the computer may be free over half the time. Eventually this extra time may be used for other jobs, but during our development phase we have preferred to use it for increased reliability.

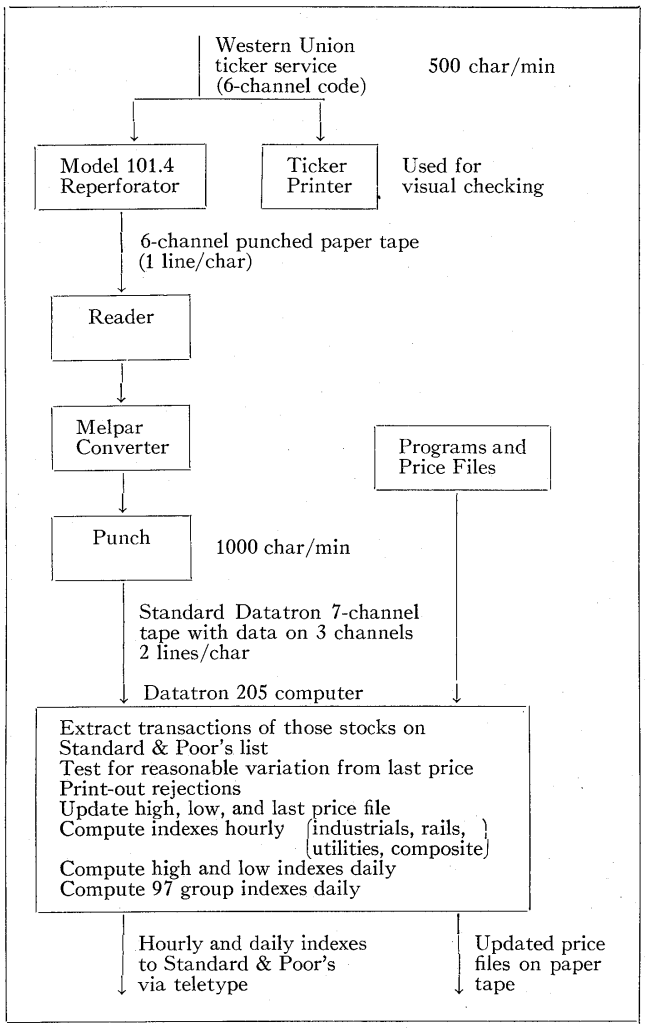


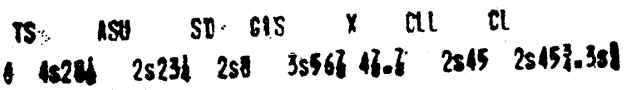
Fig. 1.

Reliability

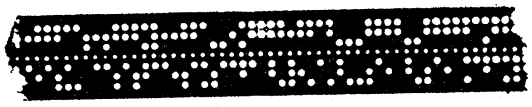
Reliability in the system is attained by hardware duplication, to be discussed later, and by programmed checks. Of the dozens of checking features incorporated into the program, the most important is the check for price reasonableness. Each new price is compared with the last previous price and, if the difference is more than approximately 2 per cent, the price is not immediately accepted but is printed out along with the old price for visual inspection. Such a "rejection" may be caused by:

1) An error on the ticker. In this case the price is properly rejected and a correction will appear later.
2) An unusual configuration on the ticker which looks like a transaction, for example, the report of a dividend in cents.
3) A legitimate price change greater than 2 per cent. The new price is inserted as a special operation.
4) A price-file error. Same as 3).
5) Malfunction of the tape-converter system. The converter is replaced by the spare.

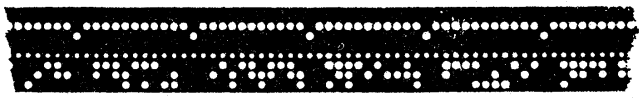
This check therefore serves not only to minimize degradation of accuracy of the answers, but as a diagnostic feature. In this connection, it is desirable to distinguish between a system error which results in degradation of the answers and one which is incapacitating.



Printed ticker



6-channel punched ticker



Ticker data converted to a 3-channel code and grouped in Datatron words. The first character in each group is the sign which is always positive. The three channels below the sprocket channel are used with the following code:

Fig. 2—Punched tape coding.

Upper Case				Lower Case			
A	30	T	01	0	42	5/8	67
B	23	U	34	1	70	3/4	65
C	16	V	17	2	63	7/8	61
D	22	W	31	3	56	b	73
E	20	X	27	4	62	⊙	44
F	26	Y	25	5	60	c	50
G	13	Z	21	6	66		
H	05	&	33	7	53		
I	14	Pr	04	8	45		
J	32	⊙	10	9	54		
K	36	¢	02	£	76		
L	11			$	47		
M	07			—	43		
N	06			*	75		
O	03			s	64		
P	15			1/8	41		
Q	35			1/4	74		
R	12			3/8	57		
S	24			1/2	71		

Fig. 3—Correspondence between printed characters and computer digit pairs.

Degradation

The computer almost never makes errors which have the effect of degradation; if it is not functioning properly, the program will quickly hang up. Therefore, the primary source of degradation is faulty data input caused by converter malfunction. However, this effect is not serious for several reasons: 1) the aforementioned rejection of gross errors, 2) errors in the input data show up as rejections and alert the operator to switch to the second converter, 3) with 500 stocks in the index an error of no more than 2 per cent in a few of them is not significant, and 4) there is

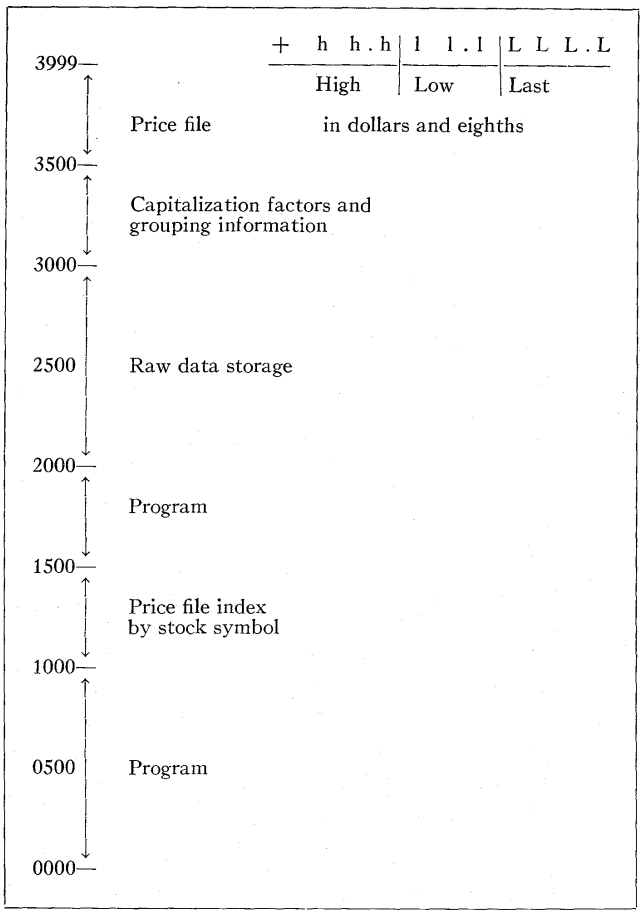


Fig. 4—Computer storage chart.

a chance that an error introduced during the hour will be replaced by a legitimate transaction before the end of the hour when the indexes are computed. (While true of last price, this is not the case for high and low.)

Thus, an acceptable level of accuracy is maintained without operating the converters in parallel, but by merely having a spare ready to insert when one shows signs of failing. The possibility of an incapacitating failure has led us to seek a measure of the reliability of a system in terms of on-line or time-sensitive work.

Time Sensitivity

There is a difference in the quality of urgency one feels about the computation of a table of elliptic functions as opposed to the computation of the trajectory of an enemy missile, for example. But this difference is not solely one of the existence or nonexistence of deadlines—the table of elliptic functions may have a publication deadline. There is a question of cost involved along with some subjective factors which can probably be converted to dollars and cents. We would like to have a formula, a technique of obtaining a quantitative measure of the fitness of a particular system to perform a given job. Such a formula to be comprehensive would be very complicated. The simple approximation of Fig. 5 illustrates what might be done.

To say that S must be less than or equal to unity is to say that the processing time cannot be greater than the interval time.

I = Interval: maximum permissible time between the availability of raw data and the completion of its processing.
P = Processing time: time required for the computer to process the data collected in interval I for which answers are required at the end of interval I.
C = Change-over time: time required to switch from the given job to another one, perform some useful work, and return to the given job.
S = Sensitivity index: a measure of the time sensitivity of a given job on a given computer:

$$S = \frac{P + C}{I + C}, \qquad 0 \leq S \leq 1$$

M = Mean error-free running time: mean time interval which a system will operate without an error.
R = Reliability index: a measure of the reliability of a particular system for a particular job.

$$R = \frac{M}{M + PS}.$$

Fig. 5—Formulas.

The closer S approaches to unity, the more time-sensitive the job is.

For special purpose systems, the change-over time may be said to be prohibitively large, therefore S is close to unity regardless of P and I.

The relation

$$R = \frac{M}{M + PS}$$

implies that, even if M is small, if the term PS can be made small in comparison to M, then a high reliability can be attained. This assumes an efficient error detection and recovery procedure so that available system time can be used to reprocess the data.

R may be regarded as the probability that the job will get done.

If an R is computed for the separate components of a system, then the over-all R is given by the product of R's for the components.

If R_1 and R_2 are the reliability indexes of two parallel systems performing the same job, then

$$R_{\text{total}} = R_1 + R_2 - R_1 R_2.$$

Operating Experience

This operation was entered into by Melpar primarily as a research project and for this reason we have had very little "typical" operation as our control programs and procedures have evolved. One result of this is that the human operators reach the point of boredom without having attained enough automatic proficiency to eliminate errors. In fact, most errors in the system have been traceable either to a human error or to faulty recovery from an equipment error not very serious in itself, thereby reinforcing our belief that human participation in such a system should be kept to a minimum. However, we have devoted considerable effort toward making it difficult for an operator to make an incapacitating error. Most such safety features take the

form of programming tricks peculiar to the Datatron computer.

A second result of the lack of "typical" operation is that the figures tabulated in Fig. 6, continuing the reliability measurement example, are based partly on extrapolations and estimates. We have done worse in the past, especially during the first few weeks of operation, but are doing better now, and expect to do much better in the future than the figures indicate.

Comments on Fig. 6

In estimating M, only those errors which resulted in delivery of late or incorrect indexes as a computer output have been counted. Accurate indexes can be extrapolated from previous ones using a few market leaders as weighting factors. This provides a level of backup to our system.

The reperforator is a well-engineered heavy-duty device. However, its large M is due in part to the fact that it is buffered from the rest of the system by the converter, an editing device.

In most cases of human error, the error was precipitated by an equipment malfunction which might have been overcome with little interference by perfect human response.

The figures used for human-linkage P and S contain a larger portion of pure estimation than the others.

Most incapacitating converter errors arise from the fact that an improperly edited data word may take the form of a control word for the computer. Tape-reading control on the Datatron 205 is exercised via special characters on the tape. An additional checking feature is being built into the converter to combat this.

	P	S	M	R per hour: Single Unit	R per hour: Duplicated	Cumulative R per month: Single Unit	Cumulative R per month: Duplicated
Reperforator	1	1	1000	0.999	—	0.862	—
Converter	0.9	0.9	50	0.984	0.9997	0.089	0.956
Human Linkage	0.4	0.4	40	0.996	—	0.548	—
Computer	0.9	0.9	60	0.987	0.9998	0.141	0.969
Composite				0.9664	0.9945	0.006	0.44

$$R = \frac{M}{M + PS}$$

Fig. 6—Reliability of components. The figures shown for composite R may be interpreted as probabilities that there will be no delay of answers or production of wrong answers during the indicated period by the system described here. Another level of backup for the "Standard 500" is provided by extrapolation and manual techniques.

Conclusion

This application has demonstrated the feasibility of processing stock market data as reported on the ticker tape. It has also afforded another example of the use of general-purpose digital computers in on-line jobs. The sensitivity and reliability indexes, while not precise measures nor always applicable, are valuable devices for use in the analysis of system performance.

It is possible to translate computer operating speed into reliability through its effect on sensitivity.

The best applications are those which have associated with them enough off-line processing to support an additional computer which also provides backup to the on-line system.

Discussion

Question: Can you indicate specifically the human links within the described system?

Answer: The converter output is a punched tape which is wound and transported to the photoelectric reader of the computer by hand. The indexes are transmitted from our Boston Laboratory to Standard and Poor's offices in New York via ordinary teletype which involves a manual keyboard entry.

Question: Have you made any cost evaluation between the described system and all-manual operations? What is the relative occurrence of error in the indexes delivered to Standard and Poor's with the computer system as with the previous manual methods?

Answer: This operation has not been done manually. Standard and Poor's did a 90-stock index before going to the present operation. This has been a research project for us and our conclusion is that the job can be done far more economically and accurately on a computer than by manual methods.

Question: How do you check the accuracy of your price files?

Answer: There are several programmed checks, such as the test for reasonableness already mentioned, designed to preserve the integrity of the price files. If the file is read out of memory and then back in again, the file is protected by the formation of a check sum. If the check sum fails to check, a price reasonableness test is run against an earlier file known to be accurate in order to pick out which price is wrong.