7. The Collection of Event Data and its Relevance to the Optimisation of Decay Heat Rejection Systems

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1. INTRODUCTION

The precision with which the reliability of DHR (Decay Heat Rejection) systems for nuclear reactors can be predicted depends not only upon model representation but also on the accuracy of the data used. In the preliminary design stages when models are being used to arrive at major engineering decisions in relation to plant configuration, the best the designer can do is use the data available at the time. With the present state of the art it is acknowledged that some degree of judgement will have to be exercised particularly for plant involving sodium technology where a large amount of operational experience has not yet been generated. This paper reviews the current efforts being deployed in the acquisition of field data relevant to DHR systems so that improvements in reliability predictions may be realised.

2. RELIABILITY DATA BANK

The SRS Reliability Data Bank (Fig. 1) comprises two stores namely the Event Data Store and Reliability Data Store.

2.1 EVENT DATA STORE

This Store is supplied with detailed information from the operation and maintenance experience of industrial and nuclear plants. The field data, comprising inventory identification, event information and operating history, is processed into the computer files of the Event Data Store which provides a feedback of information for the guidance of plant management and derived generic reliability data as one of several inputs to the Reliability Data Store.

2.2 RELIABILITY DATA STORE

This is a computerised store of reliability information ranging from lifetimes of small components to whole plants and complete assemblies. In addition to the 'field' data transferred from the Event Data Store, reliability information is obtained from the Event Data Store, reliability information is obtained from many other reliable sources, which include:

(a) Published figures in technical literature, if the quality and source are of an acceptable standard.

(b) Data accumulated in private record systems and data banks in Industry.

(c) Data obtained in proving trials and life tests.

(d) Results of laboratory tests, contracted climate and durability tests and similar exercises.

2.2.1 Computer techniques are used to process this data; for example, failure rates and other reliability parameters can be 'pooled' statistically for identical items of different manufacturers. The main purpose of the Store is to provide a comprehensive collection of high quality data for the use of Systems Analysts, Safety Assessors, Designers, Maintenance Engineers and Plant Managers. In particular, it can be used as a valuable aid in the design and operation of new and lesser known technologies where related information can be of prime importance.

In this context it is pertinent therefore, to discuss the role of data collection and the Reliability Data Store in relation to PFR, the area chosen in this paper being that of the Decay Heat Rejection System

3. THE PFR DECAY HEAT REJECTION SYSTEM

3.1 THE AREA OF REPORTING

Two independent Systems for the rejection of decay heat have been provided.

(a) A steam dump system, via the main condenser, which has been assessed separately. A flow diagram is a shown at Fig. 2.

(b) A natural circulation system, via NaK loops and NaK/Air Heat Exchangers with forced air cooling. Assessed for reliability by F. M. Davies and whose flow diagram is reproduced at Fig. 3.

The removal of the decay heat is effected by system (a) for normal shutdown conditions, such as refuelling, and together with system (b) if fault conditions exist.

In order to satisfy the reliability standard for system (a), when initiated, the system equipment already in operation should continue to operate and dormant equipment required to establish the system should operate on demand. Once the system has been established it should continue to operate for the prescribed period.

The continued removal of decay heat, under fault conditions, is facilitated by system (b) with an adequate reliability requirement to maintain a minimum heat removal capacity for a prescribed period beyond that of the steam dump system.

3.2 AVAILABILITY OF DATA

Field data, of good quality, related to the operational experience of plant designed to new, unique or complex techniques is rarely, if ever, available at the commencement of the operating life of such plants. Reliance must be placed, by the Reliability Engineer, on whatever resources are available to him which can include the Plant Designers reliability intentions, pilot plant operation, proof tests and field data from plant, conventional or of special design, which have design characteristics or an operational pattern as closely related to the subject plant as possible. The subject plant too, will have many items of conventional design which may be compared with available data on equivalent items.

In assessing the PFR/DHR system the Reliability Engineers carrying out the assessment have made use of the facilities available to them and the following sections 3.2.1 and 3.2.2 show the data applied to the Steam Dump Rejection System and the NaK Loop DHR System respectively, together with the sources of supporting data and appropriate comments as to its availability in the Data Bank.

3.2.1 Steam Dump Heat Rejection System

Table I shows the fault rates, and data sources used for the assessment of this system. Additional columns have been added to include comment.

Observations on Table I

OB1 Sources available subsequent to the assessment give pessimistic rates for the type of fault mode assessed. Only one of these sources identified the leakage mode.

OB2 The sample size of the only source added to the Data Bank does not allow fair comparison with the rate quoted in the original assessment.

OB3 An extract from an SRS Pilot Study Source indicates that no faults were recorded during 10 item years of operational service.

OB4 Several sources of Boiler Feed Pump information are included in the Data Bank. These show a wide variety of fault rates for both turbine and motor driven units. However, at the lower end of the scale the average fault rate appears to lie in the range from 3 to 7 faults per pump year.

OB5 The mode in the Data Bank most nearly related to the chosen mode, is recorded in the "TOTAL" mode, however, the source data now available indicates a wide variation of more pessimistic values.

OB6 The identifying power ranges differ from those assessed, and the values of 0.03 to 0.3/item year are quoted for motors ranging from below 100 to 1000 HP

OB7 Leakage rate given for all types of valve operation without defining gland leakage or internal leakage. It was noted however, that the higher fault rate related to the motor operated valves.

OB8 The average value has been obtained from the 'AVER' print-out. A more recent AVER gives updated information with very reliable values of the order of 4×10^{-5} faults/year. These figures include long periods of operation without incurring failure.

3.2.2 NaK Loop Decay Heat Removal System

Table II provides information on faults occurring while the DHR system is running and which fall into the category "revealed during normal operation".

TABLE I - EQUIPMENT FAULT RATES

ITEM	TYPE OF FAULT MODE	FAULTS RATE/YEAR	DATA REFERENCE	EQUIVALENT DATA BANK SOURCE (1)	COMMENT
Condensers	Leakage / Blockage	0.1	CEGB - HQ3 Lloyds-Ships data	107 15	4 additional sources now available giving a data range from 0.19 to 0.67 in the total mode. (OB1) see Note 2.
CW Pump and Screens	Failure to operate	0.15	CEGB - HQ3 DH Benn	107 109	one additional source now available (OB2)
Motorised Penstock	Inoperable	0.02	Estimated	NIL	No source available in the Data Bank (OB3)
Air Pump Unit	All causes	0.05	Edison Electric No. 63-42 " " No. 65-35 " " No. 67-23 DH Benn	87 109	No other sources available.
Air Ejector	All causes	0.01	DH Benn	109	No other sources available
Extraction Pump	All causes	0.05	Edison Electric No. 63-42 " " No. 65-35 " " No. 67-23 DH Benn	109	No other sources available
Main Boiler Feed Pump	Turbine 0.05 Pump 0.35	0.40	RA Pearse - USA experience (OB1) (2)		Based on USA statistics for a similar design of pump. Sample size: 53.5 item/yrs of operation.
10% Emergency Boiler Feed Pump	Extraction Pump 0.05 Turbine 0.05 Feed Pump 0.35 Gearbox 0.05	0.50	CEGB - HQ2 (OB2)	30	See (OB4)
10% Motor Driven Feed Pump	Feed Pump 0.35 Motor 0.1	0.45	Lloyds Ships Data	15	See (OB4)(2)
Boilers	Evaporator 0.3 Leakage Superheater 0.3 Re-heater 0.3	0.9	CEGB IAEA-SM-130/19 (Bolt & Carruthers)	80	UKAEA experience now available gives fault rates in the range from 2 to 2.5 per year
HP Feed Water Heater	Leakage (excessive)	0.17	CEGB IAEA-SM-130/19 (Bolt & Carruthers)	80	Sources now available in the Data Bank give comparable rates to that quoted
De-Superheater	All causes Failure during operation	0.0112/Demand 0.16	Estimates		No comparable sources of field data available
GI Electrical Supply System	Failure to Start Failure to run	0.003/Demand 0.0032	R. Snaith communication		No comment

Note 1 Available at time of the assessment. Note 2 (OB1), (OB2) etc., refer to amplifying notes in Observations.

Note 1: Available at time of the assessment. Note 2: (OB1), (OB2) etc., refer to amplifying notes in observations.

TABLE I - EQUIPMENT FAULT RATES

ITEM	TYPE OF FAULT MODE	FAULTS RATE/YEAR	DATA REFERENCE	EQUIVALENT DATA BANK SOURCE (1)	COMMENT
Diesel Generator	Failure to Start Failure to run	0.02/ Demand 0.2	Diesel Users Assoc. and UKAEA	132 202	Data now available for failure on demand is comparable with the quoted figure. Failure to run see (OB5).
Feed Water Regulators	Single Element Three Element	0.1 1.0	T.E. Burnup		Based on UKAEA experience. More recent data tend to confirm the quoted values.
Induction Motors	Above 250 HP Below 250 HP	0.1 0.025	AIEE Trans. Pt. II - Vol 81 - July 1962 (W. H. Dickenson)	41	Data now available quote values in the range .03 to 0.3 per item year (OB6).
Mechanical Valves	Inoperable (motor operated) Inoperable (Hand operated) Gland blow } All Seat passing } types	0.015 0.01 0.015 0.015	MI-60-54 (Rev. 1) 1961 (D. R. Earles)	7	Motor Op-range 0.5 to 0.8/ Year Manual-range .007 to 0.09/ Year Leakage mode range 0.05 to 0.2/year (OB7)
Control Valve	Failure to control	0.025	Edison Electric No.63-42 " " No.65-35 " " No.67-23 MI-60-54 (Rev 1) 1961 (D. R. Earles)	87 7	4 sources now available and give values in the range of 0.026 and 0.16 faults/year

Note 1: Available at time of the assessment.
Note 2: (OB1), (OB2) etc., refer the amplifying notesxin observations.

TABLE I - EQUIPMENT FAULT RATES

ITEM	TYPE OF FAULT MODE	FAULTS RATE/YEAR	DATA REFERENCE	EQUIVALENT DATA BANK SOURCE (1)	COMMENT
Temperature Controller	Failure to Control	0.035	Estimated		4 sources now available giving values between 0.02 to 2.9 faults/year.
Pneumatic Controller	All causes	0.067	MI-60-54 (Rev. 1) 1961 (D. R. Earles)	7	2 sources now available giving values between 0.03 and 0.17 faults/year.
Pressure Transmitter	All causes	0.088	MI-60-54 (Rev. 1) 1961 (D. R. Earles)	7	One additional source gives a more optimistic rate of 0.02 faults/year.
Electrical Relay	Failure to Operate	0.0025	MI-60-54 (Rev. 1) 1961 (D. R. Earles)	7	Several sources are available with an average rate of 0.00264 faults/year (OB8).

Note 1: Available at time of the assessment.
Note 2: (OB1) (OB2) etc., refer the amplifying notes in observations

Observations on Table II

OB9 Operational data on Dump Valves is very sparse. No 'Human Error' data, although recorded if available, has been supplied to the Bank in sufficient quantity. Supporting data, therefore, for the assessed figure cannot be given. Because of the shortage of data on these valves, faults in the gland leakage mode have not been of sufficient frequency to isolate them from the total mode, in addition, there is no comparable data involving sodium as media.

OB10 The data available was concerned with one event on DFR which describes a liquid metal leakage on a NaK/Water Steam Raising Unit.

OB11 Leakage at the blanking plate has been assumed to be a joint leakage rate. A fault rate of 1.6 x 10^{-3} faults/joint year has been selected for comparison.

OB12 This estimate has been based on the operation of solenoid operated multi-way pneumatic valves, which it is considered would constitute the main cause of malfunction of the damper. The valve chosen was extracted from a scrutiny of 3¼ years of industrial maintenance records involving some 200 valves.

OB13 As noted it is assumed the pipework is that listed previously but defining a failure mode of "blockage". Very little information is available on this fault aspect in pipework. AHSB(S)R117 suggests that leakages occur relative to 'blockages' in the ratio of 4 to 1. This would suggest an estimated rate of 0.35 x 10^{-6} f/ft year.

TABLE II - EQUIPMENT FAULT RATES

ITEM	TYPE OF FAULT MODE	FAULTS RATE/YEAR	DATA REFERENCE	EQUIVALENT DATA BANK SOURCE (1)	COMMENT
Start Button Contactor	Failure to make contact Failure to energise motor	0.005 0.016	AHSB(S)R117		The several sources available have an average of 0.08 f/year
Dump Valves	Inadvertently opened Gland Leakage	0.1 0.1	Assumed		No data available for *Human Error.* 2 sources give an average fault rate in the Total Mode of 0.15 (OB9).
Pipework (305ft)	Split	$3x10^{-6}$	GEAP 4575 10^{-8} f/yr/ft/length	70	Later sources show a wide range of data from 0.12 to 20 x 10^{-6} f/ft year, not involving sodium. One sodium medium source gives 1.7 x 10^{-6} f/ft year.
Filling Vent Valves (4 in parallel) (1 in series)	Leakage Operator error	10^{-2} $4x10^{-6}$	MI 60-54 Rev. 1 (D. R. Earles)	7	3 sources are available ranging from .001 to 0.11 f/year, with an average fault rate of 0.043. Operator error (OB9)
HE Coils (in re reactor) (165 ft of 4 in pipe)	Split	$1.6x10^{-5}$	GEAP 4575 10^{-7} f/yr/ft/length	70	Available sources indicate a fault rate of $1.4x10^{-6}$ f/ft/yr. All operating in the sodium media.

Note 1: Available at time of the assessment Note 2: (OB9)(OB10) etc., refer to amplifying notes in Observations.

TABLE II - EQUIPMENT FAULT RATES

ITEM	TYPE OF FAULT MODE	FAULTS RATE/YEAR	DATA REFERENCE	EQUIVALENT DATA BANK SOURCE (1)	COMMENT
Expansion Tank	Failure	10^{-4}	Assumed		Only one source is available giving a fault rate of the order of 1.5 x 10^{-4} f/year.
NaK/Air Heat Exchanger	Leakage	10^{-1}	Assumed		Only one source available which gives a fault rate of 0.01 f/year (OB10).
Filling Valve and blanking plate	Valve Leakage Blanking plate	0.05 10^{-4}	MI 60-54 Rev. 1 (D. R. Earles)	7	One source only available confirming the given rate of 0.05 f/year. Blanking plate (OB11)
Dump Tank Relief Valve Setting-to 25 psia	Leakage	0.02	AHSB(S)R117		Two sources of wide variation give fault rates of 0.08 and 0.36 f/year respectively. How ever a fault rate in the 'Fail dangerous' category is quoted as 0.02 f/yr
Pressure gauge (Vent line)	Leakage	0.05	Assumed as valve leakage rate		Later Data Bank sources give a fault rate, in the total mode of 0.13 f/yr.
Dump Tank Pressure Gauge	Leakage	0.05	Assumed as valve leakage rate		-ditto-

Note 1: Available at time of the assessment Note 2:(OB9)(OB10) etc., refer to amplifying notes in Observations.

TABLE II - EQUIPMENT FAULT RATES

ITEM	TYPE OF FAULT MODE	FAULTS RATE/YEAR	DATA REFERENCE	EQUIVALENT DATA BANK SOURCE (1)	COMMENT
Expansion Tank Pressure Gauge	Leakage	0.05	Assumed as valve leakage rate		Later Data Bank sources gives a fault rate, in the total mode of 0.13 f/yr.
Expansion Tank Relief Valve Setting: 25 psia	Leakage	0.02	AHSB(S)R117		As quoted for Dump Tank Relief Valve.
Isolating Valve Expansion Tank	Seat leakage	0.05	Assumed Valve leakage rate		From one available source 0.056 faults/year.
Condensate drain pot valve	Seat leakage	0.05	Assumed Valve leakage rate		Assumed to attract the comment of Expansion Tank Isolating Valve
Isolating Valve 65 psi gas supply	Seat leakage	0.05	MI 60-54 (Rev. 1) (D. R. Earles)		From one source only a fault rate of 0.056 ft/yr.
Relief Valve	Seat leakage	0.02	AHSB(S)R117		As quoted for Dump Tank Relief Valve
Non-return valve Argon make up	Failure to open on loss of pressure	0.02	Assumed valve leakage rate		Water usage sources give an average rate of 0.63 f/yr. Pneumatic applications give a fault rate of 0.16 f/yr.

Note 1: Available at time of the assessment
Note 2: (OB9)(OB10) etc., refer to amplifying notes in Observations.

TABLE II - EQUIPMENT FAULT RATES

ITEM	TYPE OF FAULT MODE	FAULTS RATE/YEAR	DATA REFERENCE	EQUIVALENT DATA BANK SOURCE (1)	COMMENT
Pneumatic actuater Damper	Fail to open	0.03			No data available in the Data Bank (OB12) (0.003 f/yr)
Pipework	Blockage	0.01	Assumed		It is assumed that this pipework is that previously listed and noted in (OB13)
Forced DRAUGHT FANS	ALL CAUSES Centrifugal / Axial				3 sources 2.1 f/year / One source 0.06 f/year
Forced DRAUGHT FANS DRIVE MOTORS	FAIL TO START OR RUN Centrifugal / Axial Fan	0.03			3 sources 0.5 f/year / One source 0.06 f/year

Note 1: Available at time of the assessment
Note 2: (OB9)(OB10) etc., refer to amplifying notes in Observations.

4. TECHNICAL DATA RECORDING AND REPORTING FOR PFR

4.1 Plans were made in the middle of 1970, for the development of a system of control and recording of engineering and operating experience of plant items and equipment. Subsequently a system of recording and retrieval of data designed to cover identification, history and performance of each listed item of plant on to computer records.

4.2 SRS and the PFR Planning Dept. have had a continuing dialogue throughout this period on the nature of the data required and means of feed back of information into the Reliability Data Store. SRS interest has been orientated towards the provision of data related to fault and operating data of plant items, which it is intended to retrieve from the Computer Store at Risley. The following computer data files are now in use,

(a) PFR Plant Inventory File

(b) PFR Plant History File

(c) PFR Plant Maintenance File

(d) PFR Permanent Data Record.

A recent communication from the Planning Dept at PFR indicates that a program has been written, and is available for use, to access the Plant History File but a unique identification of individual items has not yet been achieved. It is expected to resolve this problem later this year.

4.3 It is noted that the NaK Loop DHR System is subject to loop performance tests some 8 to 10 times per year and it is intended to monitor these tests on the Data Reduction Equipment (DRE). Under normal fault conditions the associated fault data would be channelled in to the PFR History File. However, it is not clear that fault conditions which are discovered or occur during monitoring of the performance tests will also be channelled in to the History File. It has been recommended that all faults on the DHR System, whether found during tests or not, should be properly reported and recorded in the History File.

5. CONCLUSIONS

5.1 Current techniques improving the precision with which plant/item performance can be assessed demand a high standard of reliability data ranging from fault rates in the total mode, i.e., all modes of failure, through complete failure/component modes to data giving failure per demand.

A scrutiny of the comments and observations associated with Tables I and II show that:

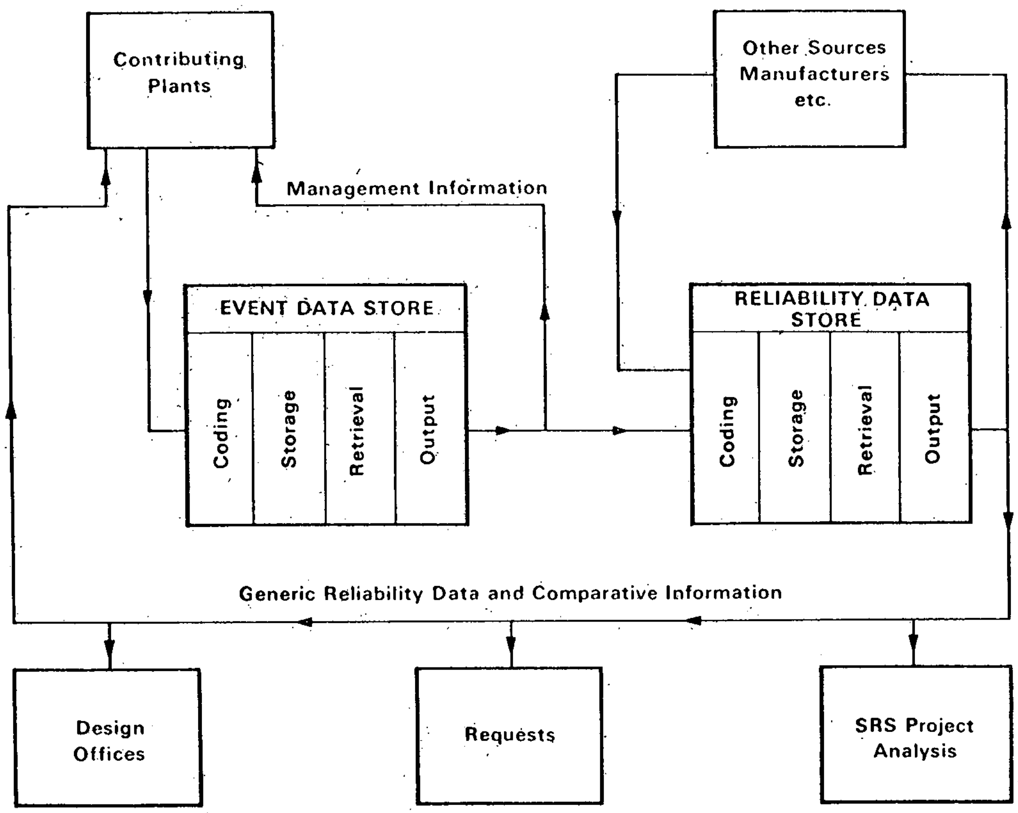
(a) Quantitative data on plant items associated with the sodium technology are very sparse.

(b) Some items of conventional plant e.g., Feed Water Regulators broken down into different element configurations, also show a scarcity of good quality data.

(c) The data which is available is largely only in the 'TOTAL' mode.

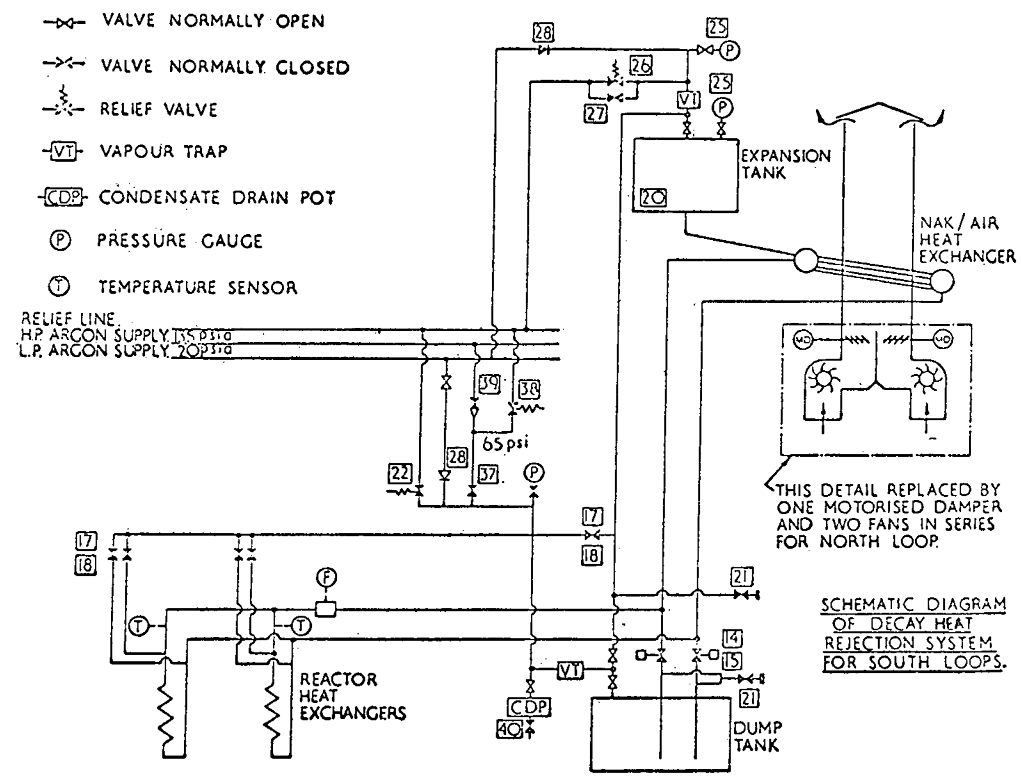
(d) Field data quantifying 'availability on demand' is also very sparse.

5.2 Accurate calculation of system reliability by computer techniques is jeopardised by the "inadequate state of good data". However, although a great deal of effort has been made to improve both the quantity and quantity and quality of the data in the Reliability Data Bank it is stressed that there is a continuing urgent need for good quality data related to selected failure modes on all types of plant items, particularly those used in liquid metal systems.



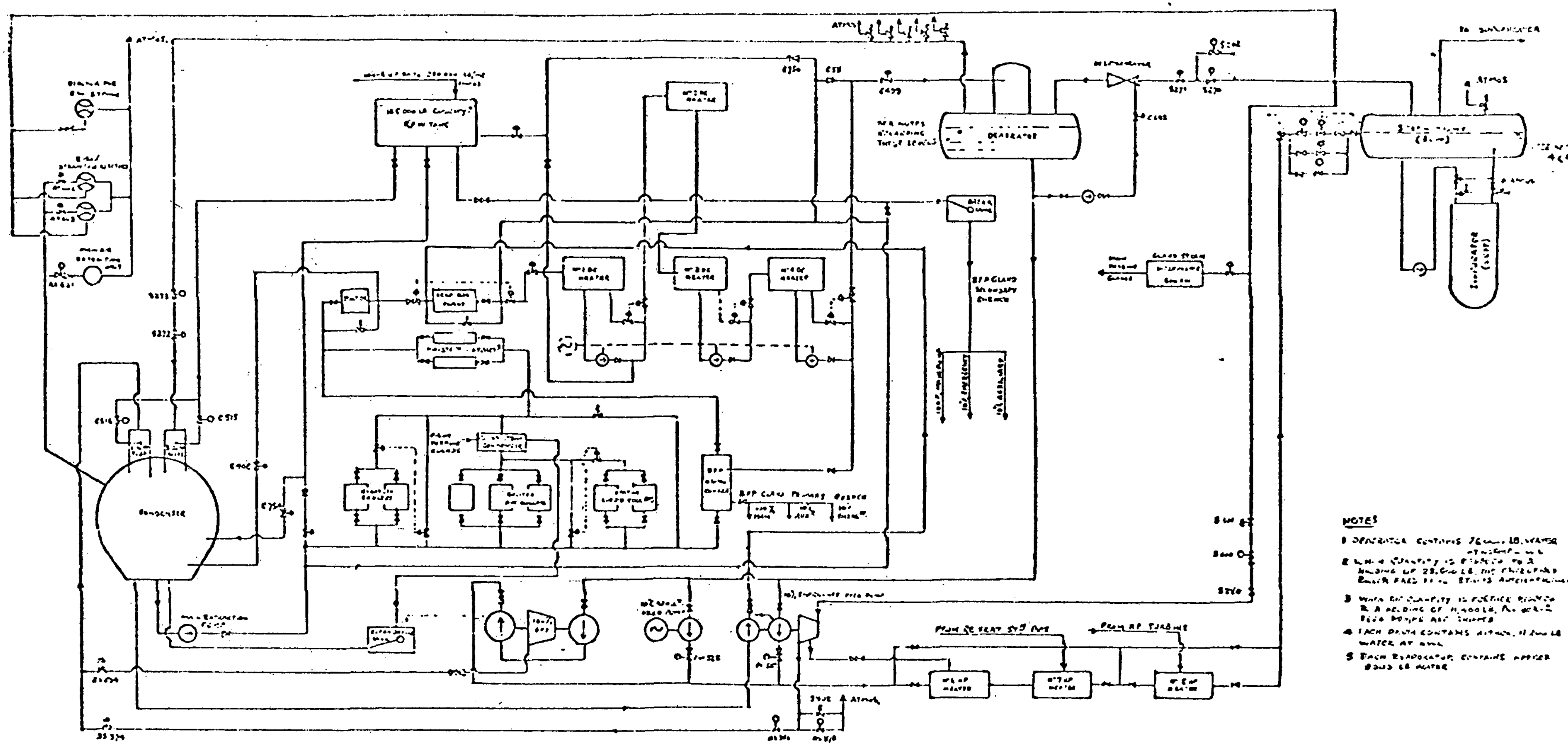
Systems Reliability Service Data Bank Information Flow

FIG. 1



FLOW DIAGRAM FOR DECAY HEAT REJECTION - CIRCUIT B

FIG. 3.



FLOW DIAGRAM FOR CONTINUOUS STEAM DUMPING WITH NORMAL ELECTRICAL SUPPLIES AVAILABLE

P.F.R. T.G. SET

FIG. 2.