lower and, furthermore, there was no evidence of corrosion after
the test. We hope that these results, presented only to serve as
typical examples, illustrate how promising is the basic research
on the mechanism of thermal decomposition and how wide is the
margin for the improvement of the performance of the organic
fluid cycles.

Analysis of Power Plant
deaerators Under Transient
Turbine Loads

R. R. Johnson. Interest and concern by consulting engineers
and operating personnel concerning the discussed problem is
shared by manufacturers of deaerators for this service since, in
effect, they have the ultimate responsibility to design and con­
struct equipment to assure their customers of proper operation
during all practical and conceivable conditions of operation.

The fact that Mr. Liao himself has now devoted two papers to
this subject is refreshing to us, since it indicates that, hopefully,
positive steps will be taken by all people associated with the
problem to come up with a cure.

There is no manufacturer who sells deaerators for central sta­
tion plant operation who has not experienced difficulties as a re­
sult of transient conditions, as described in this latest paper.

There are two types of forces occurring under transient condi­
tions which must be considered and recognized. They are:
1 Forces resulting from instantaneous differential pressures on
connections, internal baffling, trays, etc.
2 Kinetic forces, resulting from the differential pressures,
which "throw around" large masses of water. The rapid accele­
ration and high velocity which results, releases tremendous kinetic
energy which we, at Cochrane, have dubbed the "missile forces."

Mr. Liao's paper has dealt primarily with the former type of
force.

The author's analysis directs attention to alarmingly high dif­
ferential pressures and the need for adequate equalizing areas
through connecting tank nozzles and tray by-pass systems.

We fully realize that certain assumptions must be made in der­
ivation of a design approach such as Mr. Liao's. While his derived
design approach is a major step to the solution of this problem,
we feel that other steps must also be taken. His whole concept is
based on the assumption that condensate flow in the deaerator is
constant and (we assume) will not exceed maximum rated flow.

Cochrane Division-Crane Co.'s experience has been that when
transient situations occur, neither operating nor design personnel
are usually able to state with any degree of certainty the actual
condensate inlet flow rates and temperatures which exist during
this time period.

In cases where we have been able to determine actual condi­
tions during transient situations which occur during turbine trip­
out or rapid load changes, we found that inlet water flow rates
had exceeded design conditions in the magnitude of 100 percent
or greater. Diagnosis has generally indicated that this is the re­

cognized result of flow control mechanism response to a false reading or sig­

nal because of rapid ebolutions and change of specific gravity of
this time period.

Cochrane Division-Crane Co.'s experience has been that it is
impossible for engineers to specify precisely what occurs during
transient conditions such as turbine tripout; for example, conden­
proach and provision of sufficient equalizing area as calculated,
the problem described by the author can still occur with resultant
internal structural damage. Further, if the illustration cited by
the author is expanded to much greater sizes of deaerating equip­
ment which have and are being purchased, it is questionable
whether the calculated equalizing area can be provided from a
practical and economic point of view.

As an example, we applied Mr. Liao's analytical approach to a
job which we recently quoted and calculated that we would have
had to provide approximately 10 to 15 42-in. dia equalizers be­
tween the deaerator and the storage tank.

As deaerator manufacturers, we have accumulated as much
data from utilities and consulting engineers as possible on this
problem. The indications we have are that more damage is done by
the "missile" effect than by the differential pressure loadings.

These loadings, cited previously, result from the sudden throw­
ing around and/or change of direction and/or rapid acceleration
of masses of water from two sources:
1 Water in transit between the deaerator and storage section.
2 In some cases, depending upon the design used, some por­
tions of the water in the storage tank.

What then, are the answers to this problem? There are several,
which when combined, require a cooperative effort of the equip­
ment designer, evaluating engineers, buyers and plant operators.

Equipment Designer
1 As Mr. Liao has so well pointed out, the designer must pro­
vide the maximum practical equalizing area between the deaerating
and storage sections, as well as the maximum practical relieving
devices to prevent excessive pressure differential buildup
across the deaerator tray stack and enclosure.
2 Design the internal structure of the deaerator to minimize
in-transient water volumes which represent a potential missile
mass which could be thrown around during a back-flow or back­
surge situation.
3 In cases where such requirements are not specified, avoid
elaborate systems in the deaerator storage tank for distribution of
water over the entire surface of the tank, direct to pump supply
arrangements and other concepts which conceivably make the en­
tire volume, or an appreciable percentage thereof, of the stored
water to be misdirected back into the deaerator in the case of
sudden reverse pressure differentials.
4 Provide adequate structural rigidity and baffling to prevent
missile loading from impinging directly on vulnerable components
such as trays, tray enclosures, etc. Minimize use of stainless steel,
where economy dictates lighter gauge structural members and en­
closures. Make more liberal use of carbon steel which provides
more rigid construction due to the ability to use heavier compo­
nents at lower cost.
5 In cases where the equipment designer is responsible for siz­
ing control valves, etc., avoid oversizing of this equipment so that
more accurate level control can be achieved.

Specifying and Evaluating Engineers
1 Where possible, avoid requirements for "direct to pump
supply," "distribution of water over the entire volume of stor­
age," etc.
2 The "kitchen wear" glamour of stainless steel has resulted
in a vicious cycle over recent years wherein, more and more, spec­
ifications are requiring such materials. This, in combination with
the profit squeeze usually results in a flimsy design. Many of the
areas where stainless steel is now specified could be eliminated
since corrosiveness is of little or no consequence whereas rigid
construction is highly important.
3 Specify working levels for storage tanks as low as possible
and which are economically feasible so that maximum volume
can be provided above this water level to minimize or avoid water
being carried back into the deaerator during transient conditions.
4 Cochrane Division-Crane Co.'s experience has been that it is
impossible for engineers to specify precisely what occurs during
transient conditions such as turbine tripout; for example, conden­

1 By G. S. Liao, published in the July 1973 issue of JOURNAL OF ENGI­
171-179.
2 Manager, Mechanical Equipment Department, Cochrane Division-
Crane Co., King of Prussia, Pa. Mem. ASME.
sate inlet flow, temperature, and rate of change of same. This is understandable, and to compensate for this, it is important that the evaluating engineers analyze thoroughly the internal construction of equipment when proposed. They should satisfy themselves as to what the equipment provides in the way of those items previously described as being the responsibility of the equipment designer.

Operators
1. Designate flow control devices to sudden apparent level changes by using large proportional bands.
2. Do not raise intended working levels of storage tanks by adjustment of control point.
3. Take every precaution to minimize operator caused transient conditions. This is particularly critical during start-up and shut-down procedures.
4. Provide complete and thorough training of operating personnel to familiarize them with the internals of the equipment, how it operates, and precautions which must be taken so that operator caused errors can be minimized or eliminated.

Buyer
1. Coordinate purchasing of deaerating equipment with the evaluating engineers, so that proper credit is given to those units which are proposed with maximum internal rigidity and structural integrity; do not buy on “bottom line” price only.
2. In summary, Mr. Liao’s work is a giant step to the solution of this problem; however, we feel that additional steps must be taken as described to insure the complete and ultimate cure. The mutual recognition of the problem and cooperation of all parties concerned with this equipment is absolutely necessary.

A completely new approach must be taken in the design and manufacturing of deaerating equipment for central station application.

Crane-Cochrane has recently introduced a “high reliability deaerator” for this purpose. We have started and are continuing to conduct an educational program with consulting engineers and utilities on this subject. The basic principal of design of this deaerator is to provide all of the features as discussed under the responsibilities of the equipment designer previously.

However, for this concept to succeed, it must be recognized that this type of construction is more costly and evaluating engineers and buyers must give proper credit for it when purchasing.

Wen-Juin W. King,3 In a nuclear generating station, where no reliable, separate, or independent off-site power is available to the plant site, the station may be designed as a self-sustaining unit. The generator supplies its station auxiliary load when separation occurs to the generator and the network. The steam admission valves of the turbine have to ramp back fast so that the turbine will ride through the over-speed transient without a turbine trip. The control valve should remain open during the transient. The reactor control rods have to run into the core fast so that the reactor trip-out is considered a double failure, the control valve regulating the flow to the deaerator was over-sized. This might happen only when the condensate flow rate, condensate temperature and its rate of change, etc., following a turbine trip-out. I would like to point out that equipment design requires only the worst operating condition rather than actual operating conditions which may vary from time to time. Accordingly, a deaerator should be designed structurally for the maximum possible condensate flow which can be reasonably determined and specified, once the design criteria have been established. Regarding the condensate temperature, reference should be made to the analysis presented in reference paper [1], since the varying condensate temperature approach for determining the temperature of condensate entering the deaerator was introduced therein. Instead of utilizing a well-founded engineering approach, Mr. Johnson advocated that a deaerator should be designed on ambiguous bases such as “maximum practical,” “adequate,” “minimize,” “economically feasible,” etc. The author cannot agree, especially following numerous deaerator outages in recent years, with such a design approach which might have been satisfactory a decade ago. It should be pointed out that the recent deaerator troubles, in my opinion, have resulted from indiscriminate scale-up of existing models, on such arbitrary basis to meet new high capacity demands without considering or analyzing some other critical conditions. With today’s huge capacity deaerator, reliability and availability cannot be assured without thorough analysis based on reasonably conservative assumptions. I do not believe that the deaerator design can just rely on the expedient guess, even if it is based on the accumulated data and past experiences obtained from comparatively smaller models.

Mr. Johnson indicated that the condensate flow under transient load had exceeded design conditions in the magnitude of 100 percent or greater. This might happen only when the condensate control valve regulating the flow to the deaerator was over-sized. With a properly sized control valve, maximum condensate flow should not be more than 50 percent of the design condition, even if considering the valve wide open as a result of control air failure. It should be pointed out that the use of design condensate flow recommended for transient analysis in my paper is conservative based on single failure criterion. The simultaneous occurrence of control valve fail-open and turbine trip-out is considered a double failure. If the system is to be designed for double failures, the condensate flow at the valve wide open must be used.

According to his accumulated data, Mr. Johnson stated that more damage had been done by the missile effect resulting from the sudden throwing of water from the storage tank to the trays. However, it should be noted that the impingement of water on the trays (so called missile effect) might actually be due to i-

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3 Reectel Corp., Gaithersburg, Md.
adequately sized pressure equalizers. If the deaerating section should be flooded due to under-sized pressure equalizers, the flashing steam from the storage tank must penetrate a thick layer of water to reach the trays. As a result, large masses of water carried by the flashing steam are thrown around on the internals of the deaerating section. Therefore, the missile effect, which is in Mr. Johnson's opinion the major cause of internal damage, is in effect a direct consequence of under-sized equalizers. There are, of course, some other design parameters which can cause the missile effect, such as too little volume above the storage tank water level, inadequately designed drain pipe through which the flashing steam can blow, etc. Those factors are rather obvious and should be taken care of by deaerator designers.

Mr. Johnson also questioned whether the calculated equalizing area can be provided from a practical and economic point of view. He cited that approximately ten to fifteen 42 in. dia equalizers would be required for his application. However, I would like to point out that the two 42 in. equalizers in my example calculations are for a 750 MW unit. It is not conceivable, therefore, that any generating unit now under consideration ever requires such a large equalizer area. It should be emphasized that the calculated equalizer area must be provided without compromise, if the flooding of the deaerating section, as well as the missile effect on the internals, is to be avoided. As to the practicality of providing them, number and size of pressure equalizers can be reduced by increasing the static head for the drain pipes. In order to increase the static head and at the same time prevent steam blow back, the drain pipes may be extended down into the steam space of the storage tank and adequately sealed.

I recognize that the causes of the deaerator failures are numerous. However, the two critical design considerations presented in this paper are the major causes of the failures under transient operation. In order to ensure satisfactory and reliable operation of deaerators, a power plant engineer who is familiar with the system and knows all conceivable operating conditions should specify the worst operating condition and make related data available to deaerator manufacturers for their design.

Mr. King mentioned the importance of evaluation of the pressure decay in the storage tank, and indicated that the transient equations were to be derived to demonstrate the reactor-turbine response. I agree with him, if no bleeder stop check valve is provided in the extraction steam line. Without bleeder stop check valve, the pressure decay in the deaerator will closely follow the extraction steam pressure decay; thereby the presented method which assumes the deaerator to be isolated by a bleeder stop check valve, is not applicable. However, this method is valid, if a bleeder top check valve is provided, and the extraction steam pressure decay is greater than the deaerator pressure decay rate. In other words, the deaerator is to be isolated from the main turbine, thereby neither receiving extraction steam nor losing flashing steam.

Mr. King indicated that the steam admission valves have to ramp back fast to prevent the turbine from over-speed trip with the intercept valve kept open. If this is the case, the extraction pressure decay rate will be far greater than the deaerator pressure decay rate, and a bleeder stop check valve is required in the extraction line to isolate the deaerator, even if the main turbine does not require it. Under this mode of operation, the reactor-turbine response, which determines the extraction steam pressure decay rate, is inconsequential for the analysis.

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**ASME Steam Turbine Code Test Using Radioactive Tracers**

C. B. Scharp. This paper is an extremely important contribution to the technical literature, and the authors should be commended for sharing their experience with us. Feasibility tests of the tracer method for determining moisture content, as reported in reference [1] of the paper, was incorporated into the Interim Test Code for Steam Turbines, reference [3], published earlier this year. Because this technique was not well known in performance testing applications, PTC Committee No. 6 on Steam Turbines decided to issue PTC 6.1 as an Interim Code for Trial Use and Comment. Each application of the technique has been more encouraging and this paper, which describes the latest results, is the most encouraging to date. It is extremely gratifying to see the good repeatability and consistent results obtained in the Millstone tests.

The paper also describes the sampling equipment required and details of the injection and sampling taps. This should help to remove some of the mystery involved in this technique and aid engineers in planning for tests on units operating on wet steam. The writer visited Millstone plant during the tests described in this paper and I was quite impressed by the completely different nature of the test equipment from that used in tests of superheated steam turbines. These are described in the paper in detail and shown in Figs. 9 through 12.

This is the first report of the use of radioactive tracers in measuring flow. Agreement to within 1 percent of the flow measured by venturi is quite good, and the authors should be encouraged by this result.

It will be interesting to see if the comparisons shown in this paper are improved or worsened in tests of turbines receiving steam from pressurized water reactors.

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**Performance of Perforated Heat Exchanger Surfaces**

C. P. Howard. It is always a pleasure to have a paper from Bob Mondt and his colleagues, for you know it will be relevant and of excellent quality. I do not know if I can answer all of his questions—but I do have some opinions.

The performance of perforated surfaces when compared on the basis of a nonperforated area in the laminar flow region is about equal to the nonperforated surface performance. Previous test results for perforated surfaces, from 12-50 percent open area, have been replotted on a solid area basis and, indeed, show no effect of the removed material (see Figs. 11 and 12). The perforation geometry, of course, should be specified (see Table 3).

The advantage of the perforated surface is in the high Nu region of actual heat exchanger operation where the perforations...