Modernized the Fire Protection Facilities in Oil Refinery by Evaluating Risk and Hazards as per Safety using Practice Approach

Yogendra Singh[1] Nisha Kushwaha[2]
[1]PG Scholar [2]Assistant Professor and Department Head
[1,2]Shiv Kumar Singh Institute of Technology and Science, Indore, India

Abstract— The oil industry in India is over 100 years old. Variety of practices has been in vogue because of collaboration / association with different foreign companies and governments. Standardization in design philosophies & operating and maintenance practices at a national level was hardly in existence. This coupled with feedback from some serious accidents that occurred in the recent past in India and abroad, emphasized the need for the industry to review the existing state of art in designing, operating and maintaining oil and gas installations. With this in view, Oil Industry Safety Directorate (OISD) was established in 1986 staffed from within the industry for formulating and implementing a series of self-regulatory measures aimed at removing obsolescence, standardizing and upgrading the existing standards to ensure safer operations. The present document on 'Fire Protection Facilities for Petroleum Refineries & Oil/Gas processing plants is basically the modernizing phenomena implemented in Reliance refinery of the country. Attempts have been made to incorporate the latest technological changes, experience gained in its implementation during last 4-5 years and relevant changes in the light of various national and international codes and practices. It is hoped that the provision of this document, if implemented objectively will go a long way in improving the safety in the oil & gas industry.

Keywords: Reliance Refinery, Plant Layouts, Mathematics, Theoretical Background, Standard Codes, PPE's, Practical Methodology, Risk And Hazards, Safety, Fire Safety Measures

I. INTRODUCTION

This report provides an overview of methodologies which can supplement existing risk management practices, with particular reference to major hazards. It is written with petroleum refining and large scale storage installations in mind although many of the principles involved are applicable to the transport of petroleum feedstock and products by road, rail, sea and pipelines. The report is not intended as a manual for the specialist, but rather for all persons who wish to be informed about these developments and their applicability. As this report serves as an overview it should be borne in mind that the data therein contained are quoted for illustrative purposes and should not be interpreted.

Fig. 1: INDIAN Oil Refineries [1]

The requirement of firefighting facilities, described in the following chapters is based on the consideration that the firefighting services from city fire brigade and/or from other neighboring industries will not be available.

1) This standard covers the design criteria and details of the various fire protection facilities to be provided in petroleum refineries and oil/gas processing plants.
2) This standard also covers the facilities located within the refineries and oil/ gas processing plants which may include:
3) LPG storage, handling and bottling plants, [2]
4) Marketing & Pipeline Terminals with their loading / un-loading/ pumping and handling facilities.
5) This standard does not cover the facilities located outside the premises of Refineries & gas processing plants such as LPG mounded storage, handling & bottling plants, LNG storage Petroleum Depots, Terminals, Lube Blending plants & Pipeline Installations located outside.
6) However, this standard shall be applicable to those of above mentioned facilities located outside the premises under the same management and in close proximity to the refineries & gas processing plants. For such cases, common firewater storage and pumping facilities may be considered [3].

A. The Management of Risk:

Before describing the methodologies of hazard analysis and risk assessment firstly consider the practice of risk avoidance and control as part of management's responsibility for reliability. As design and process technology has evolved and the complexity of operations has increased, safety standards have been developed and improved throughout the industry. Some differences occur which reflect company preferences, local circumstances and statutory requirements of the country in which the installation is situated [13]. Thus management is increasingly concerned with the need to identify analyze and assess hazards at all stages in the life cycle of an installation, from the initial project proposal through to final shutdown. This systematic approach enables management to rank potential hazards in order of priority, thereby enabling risk to be reduced in a realistic and cost effective manner. The stages consist of various factors like

1) Planning
2) Process design
3) Design engineering
4) Construction and commissioning
5) Operations
6) Final shutdown

Risk management within this life cycle depends on the following [14]:

1) Sound standards of engineering design must be used.
2) Quality control procedures must ensure that all equipment conforms to design specification.
3) All equipment must be inspected, maintained and tested at suitable intervals.
4) Personnel must be experienced and trained in the use of clearly defined procedures.
5) Failure to apply these principles will almost certainly invalidate the use of results from any of the modem systematic hazard analysis techniques.
6) For the majority of installations, the level of risk can be judged from relevant accident statistics. However, there are cases where this may not be feasible or realistic e.g. for a new process installation of unprecedented size, modifications to an existing plant or when design standards have been improved.
7) In such cases there is a need for additional techniques to assess the level of risk to life, property and the environment.
8) These techniques are complementary to the more pragmatic ways of problem identification and assessment. They highlight how hazards can occur and provide a clearer understanding of their nature and possible consequences, thereby improving decision-making.
9) They range from relatively simple qualitative methods to advanced quantitative methods in which numerical values of risk are derived.
10) They are most effectively applied during the planning, process design and design engineering stages when it is generally possible to make changes which are less expensive than when the plant is being built or is operational. In practice, such methodologies have been used to examine plant sitting, lay-out, improve safety levels in operating and maintenance systems and solve technical problems.
11) It is within this context that the various methodologies described comment on management of risk would not be complete without reference to the importance of well-planned and rehearsed emergency procedures, to minimize the possible effects of an incident, should it occur. Such procedures include communications, fire-fighting. Personnel protection and medical treatment, provision for seeking assistance and evacuation.
12) The possible impact of incidents on adjoining installations must also be borne in mind. If there is a potential risk to neighboring communities or amenities, then there must also be co-ordination with the local authorities' emergency plans.
13) Regular training, including exercises in emergency procedures, fire-fighting drills, etc., helps to maintain a high state of preparedness, and often points to improvements in the emergency plans.

B. *Hazard Indices:*

A number of differing quantitative techniques have been developed all of which use logical simulation models [20], numerical data and mathematical computations. The applications of these methods are currently increasing and care should be taken not to exceed their inherent or logical limits. Conceptually, virtually all of these methods fall into one of the following five categories or attempt to adapt the original concept to special circumstances.

1) Fault Tree Analysis (FTA)
2) Failure Mode and Effect Analysis (FMEA)
3) Random Number Simulation Analysis (RNSA)
4) Techniques for Predicting Human Error (THERP)
5) Epidemiological Analysis

C. *Fire Protection Philosophy:*

The size of process plant, pressure and temperature conditions, and size of storage, plant location and terrain determine the basic fire protection need. Layout of an installation shall be done in accordance with OISD-Standard-118 [22] on Layouts to ensure adequate firefighting access, means of escape in case of fire and also segregation of facilities so that the adjacent facilities are not endangered during a fire. Material of construction for infrastructure facilities shall conform to National Building Code (NBC) / statutory regulations [23]. The following fire protection facilities shall be provided depending upon the nature of the installation and risk involved.

1) Fire Water System
2) Foam System
3) Clean Agent Fire Protection system
4) Carbon Dioxide System
5) Dry Chemical Extinguishing System
6) Detection and Alarm system
7) Communication System
8) Portable firefighting equipment
9) Mobile firefighting equipment

Iraj Alimohammadi et.al [30] Hydrocarbon bulk storage tank fires are not very common, but their protection is essential due to severe consequences of such fires. Water spray cooling system is one of the most effective ways to reduce damages to a tank from a fire.

Begum Dogan et.al [31] Errors that can occur in the identification studies for hazards and risks which is one of the elements of a process safety management cause resulting major accident having undesirable long - term effects on human and environment.

Osabutey D et.al [32] Risk management refers to an interactive process consisting of steps, which when undertaken in sequence, enable continual improvement in decision making.

Sunil Jayant Kulkarni et.al [33] Environmental friendly and safe operations and processes are always desired from health perspectives. Due to properties of chemicals in petroleum sector, the chances of accidents are high. Material, substances, processes or circumstances which pose threat to health and well-being of workers in any occupation are termed as occupational hazards.

Jose Luis Fuentes-Bargues et.al [35] the size and complexity of industrial chemical plants, together with the nature of the products handled, means that an analysis and control of the risks involved is required.

Faith Eyayo et.al [36] Occupational Health Hazard which is different from Occupational Safety Hazard is prevalently on the rise as industrialization increases in the global world. And identifying them in order to prevent and control them is very imperative to the health and well-being of the workers.

II. Company System

Reliance entered the Exploration and Production (E&P) business by becoming a 30% partner in an unincorporated joint venture with Shell (erstwhile BG) and ONGC in the Panna Mukta and mid and South Tapti blocks. Our domestic portfolio comprises of five conventional oil and gas blocks in Panna Mukta Tapti (PMT), Krishna Godavari, Mahanadi & Gujarat Saurashtra and two Coal Bed Methane (CBM) blocks in Sohagpur East and West in Madhya Pradesh.

Fig. 2: Reliance Petroleum Refineries [39]

Petroleum refining and marketing (R&M) is the second link in Reliance's drive for growth and global leadership in the core energy and materials value chain. The Jamnagar manufacturing division is the world's largest refining hub. The entire refining complex was built in a record time at globally competitive capital costs – in fact, at costs much lower than comparable refineries around the world. Its scale, design, flexibility, level of automation and degree of integration heralded the way refineries of the future would be built. The speedy growth of the complex lies at the heart of India's transformation. It has transformed India from being a net importer of petroleum products to a net exporter, thereby ensuring the nation's energy security. With crude processing capacity of 1.24 million Barrels per Stream Day (BPSD), the Jamnagar refinery is a trendsetter and has won several awards, including the prestigious 'International Refiner of the Year' award. It also enjoys the distinction of housing some of the world's largest units, such as the Fluidized Catalytic Cracker (FCC), Coker, Alkylation, Paraxylene, Polypropylene, Refinery off gas (ROG) cracker and Pet coke gasification plants.

III. Refinery Methodology

We now present a typical refinery flow sheet for the refining of Middle Eastern crude oil. There are about 22 units in the flow sheet which themselves are complex enough to be regarded as process flow sheets. Further, all streams are numbered to summarize their significance in various processing steps encountered in various units. However, for the convenience of our understanding, we present them as units or blocks which enable either distillation in sequence or reactive transformation followed by distillation sequences to achieve the desired products. The 22 units presented in the refinery process diagram are categorized as:

1) Desalting process
2) Crude distillation unit (CDU)
3) Vacuum distillation unit (VDU)
4) Thermal cracker
5) Hydro-treaters
6) Fluidized catalytic cracker
7) Separators
8) Naphtha splitter
9) Catalytic Reformer
10) Alkylation and isomerization
11) Gas treating
12) Blending pools
13) Stream splitters
14) Claus process

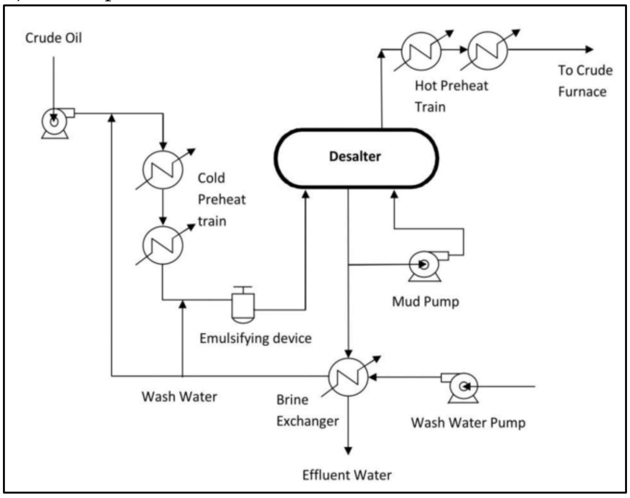

Fig. 3: Crude oil desalting process [41]

Amongst the crude distillation products, naphtha, kerosene has higher product values than gas oil and residue. On the other hand, modern refineries tend to produce lighter components from the heavy products.

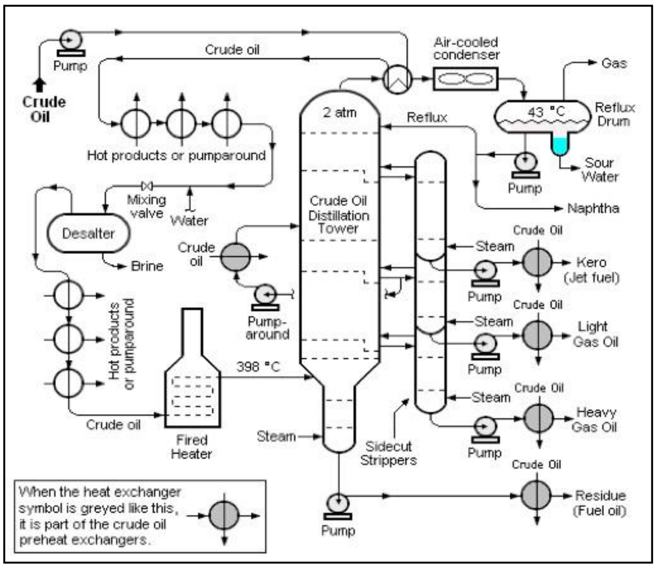

Fig. 4: Crude oil atmospheric distillation process [42]

Product	Lower C limit	Upper C limit	Lower B.P	Upper B.P
Refinery gas	C_1	C4	-100	-1
L.P.G	C3	C4	-42	-1
Naphtha	C5	C17	36	202
Gasoline	C4	C12	40	216
Kerosene	C8	C18	126	230
Diesel	C10	C22	220	255
Fuel oil	C12	>C20	265	421
Lubricant oil	>C20		>343	
wax	C17	>C20	302	>343
Asphalt	>C20		>343	
Coke	>C50		>1000	

Table 1: Properties of Petroleum distillation products

A. Basic Operations and Terminologies:

1) Vacuum distillation unit (VDU)
2) Crude Distillation Unit (CDU - 1)
3) Heavy Crude Unit (CDU – 2)
4) New Crude Distillation Unit (CDU – 3)
5) Feed Preparation Unit (FPU / HVU / VDU)
6) Fluid Catalytic Cracking Unit (CCU / FCCU)
7) Hydro-Cracker Unit (HCU)
8) Lubricating Oil Base Stock (LOBS)
9) Reformer Feed Unit (RFU)
10) Naphtha Hydro-Desulphurization Unit
11) Catalytic Reforming Unit (CRU)
12) Aromatic Extraction Unit
13) New Solvent Unit (NSU)
14) Bitumen Blowing Unit (BBU)
15) Methyl Tertiary Butyl Ether (MTBE) Unit
16) Diesel Hydrodesulphurization (DHDS) Unit
17) Sulphur Recovery Unit (SRU)
18) Treating Units
19) L.P.G Plant

IV. RISK MANAGEMENT AND HAZARD

As shown in Figure 5, risk assessment forms a key part of the overall hazard management process, since its main purpose is to identify and assess risks so that can be adequately managed. Guidance from the Health and Safety Executive stresses that the level of effort devoted to risk assessment should be proportionate to the magnitude of the risks in question. In line with this guidance, PROJECT adopt a bow-tie type approach that attempts to systematically identify a large number of potential hazards, regardless of the potential risk, which can then be screened in order to focus further effort and assessment on the hazards that contribute most to the risk.

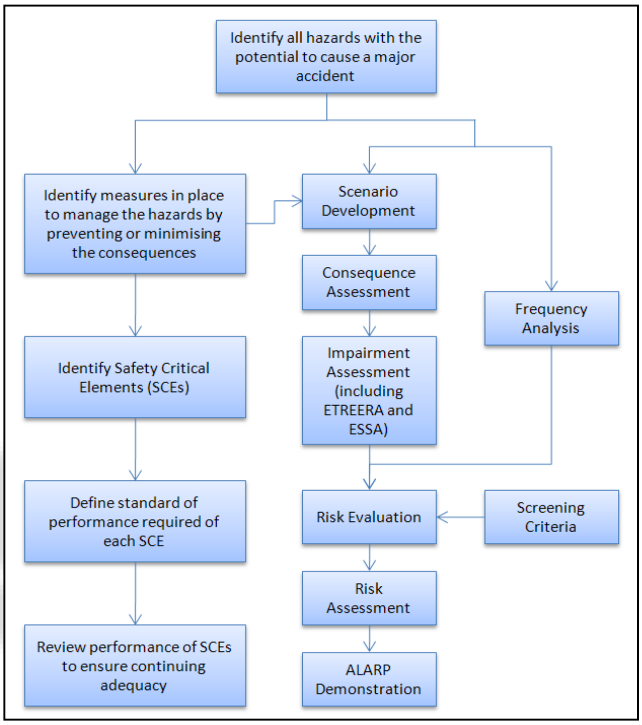

Fig. 5: Risk management process in Refinery

Quantitative risk assessment is a structured method of identifying and assessing major accident hazards associated with an installation. Quantitative risk assessment uses and provides information on the likelihood and consequence of potential accidents, and is an essential input to decision-making during the life of an asset.

Key safety-related decisions include the identification of cost-effective risk reduction measures and the demonstration that risks on the facility are ALARP. The quantitative risk assessment methodology used to assess risks associated with involves the following key stages:

1) Hazard identification.
2) Hazard event frequency analysis.
3) Consequence analysis.
4) Risk evaluation.
5) Assessment of risk.

A. Hazardous Wastes and Hazards System

1) Spent Catalysts
2) Environmental, Health, and Safety Guidelines
3) Other Hazardous Wastes
4) Non-hazardous Wastes
5) Noise

6) Chemical Hazards
7) Major Hazards

The pump house can be said to be the heart of the fire fighting system. The pump house supplies the pressurized water in the hydrant network which is laid in the entire area. The pressure in the hydrant system is maintained at 8 kg/ cm^2. The sea water is stored in two basins of total capacity of 13000 m3.

- KW305D- Biocide
- DT7747- Dispersant
- KWBDNF- Bio dispersant
- N7330- Biocide
- N7308- Bio dispersant, surfactant.

There are a total of 11 pumps in the pump house.

S. No		Specification	Quantity/ Configurations
1.		Number	05
2.		Capacity	800 m^3
3.		Working Pressure	10 kg/m
4.		Rpm	1500 RPM
5.		Amps	35-38
6.		Motor	
	a)	Make	Crompton Grieves
	b)	Power	340KW/456HP
	c)	Volts	6600
	d)	Full Load Efficiency	94%
7.		Pump	
	a)	Total Head	103.35 m
	b)	Rate of Flow	222.22
	c)	Pump Input	305.99 KW
	d)	Prime Mover Rating	340.0 KW
	e)	Size	350 mm

Table 2: Electric Drive pump Specifications

S. No		Specification	Quantity/ Configurations
1.		Capacity	800 m^3
2.		Working Pressure	10 kg/cm^2
3.		RPM	1500
4.		Gear Box	
	a)	Ratio	1:1
	b)	Vertical RPM	1500 @536 HP
	c)	Minimum Vertical RPM	450
7.		Pump	
	a)	Pump Make	Kirlosker
	b)	Total Head	103.35 m
	c)	Size	350 mm
	d)	Pump Input	305.99 KW
	e)	Impeller Diameter	CF8M/433
	f)	Direction Of Rotation	Clockwise
	g)	Recommended Prime Mover Rating	540 HP
8.		Diesel Engine	
	a)	Make Limited	Cummins India
	b)	Model	VTA1710P
9.		Diesel Tank	1000 liters (for 1, 2, 3) 400 liters for no 4
10.		Jockey Pump	
	a)	Capacity	400 m^3
	b)	Working Pressure	10 kg/cm^2
	c)	Rpm	1495
	d)	Amps	16 amp

Table 3: Diesel engine drive pump specification

Switch no	Setting	Electric/Diesel
1	6.0 kg/cm2	1/2
2	5.5 kg/cm2	2/4
3	5.0 kg/cm2	5/3

Table 4 Automatic setting of pump

B. Classification of Water Tanks for Fire Protection

Fig. 6: Geodesic roof tank (Dome Shaped) [51]

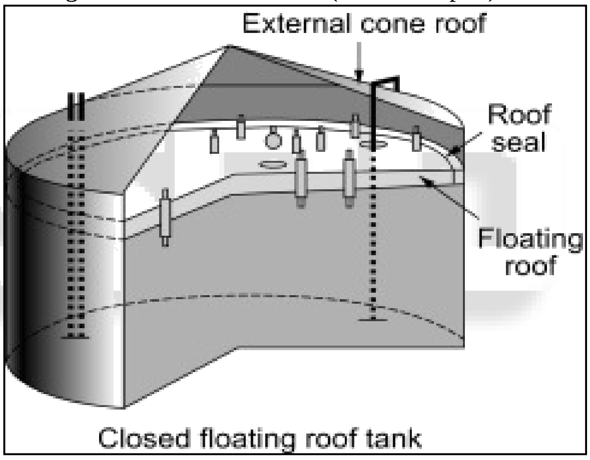

Fig. 7: Cone Roof Tanks [51]

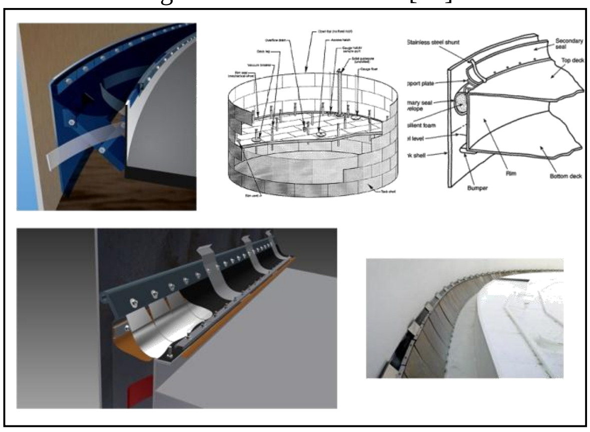

Fig. 8: Floating Roof Tank [51]

Fig. 9" Fixed cum Floating roof tank [51]

C. Foam System

- AFFF
- AR-AFFF
- Fixed Foam System
- Semi-Fixed Foam System
- Mobile Foam System

D. Maintenance and Testing

Diesel Pumps are operated for ten minutes at the beginning of every shift. The sequence of their daily test is

- Fire Pump 1 and 2 at the beginning of Shift I
- Fire Pump 2 and 3 at the beginning of Shift II
- Fire Pump 5 at the beginning of Night Shift.
- The shut off pressure is tested monthly and the performance test is conducted every six months.
- Jockey Pumps are operated daily for ten minutes.
- The Shut off Pressure is tested once in a month.
- Sump Pumps are operated daily and servicing is done once in three months.
- Air Compressors are operated daily and servicing is done once in three months.
- Bore Well Pump is operated daily and servicing is done once in three months.
- Deluge can refer to large quantity of water. Deluge Systems are intended to deliver large quantities of water over a large area in a relatively short period of time. This becomes particularly important when dealing with gaseous fires as the large amount of water not only cools the area but also displaces the oxygen and hence extinguishes the fire. The deluge system utilizes Medium Velocity Spray System which has nozzles open to the atmosphere. The deluge valve prevents the water from flowing out of the open nozzles. The deluge valve can be EPD actuated, manually operated from the site or actuated from the control room (for deluge valves in the bottling plant).
- The deluge valve in the loading gantry and the train wagon gantry are actuated by QB i.e. Quad gel Bulb fixed on an air line. When the temperature raises to the predetermined temperature the QB breaks and the air in the line escapes. This activates the solenoid valve (S.O.V). The S.O.V allows the water in the chamber to escape. As the water escapes the diaphragm rises allowing the water in the D.V to flow to the sprinklers. Once activated the D.V has to be manually stopped.

V. Discussion, Conclusion and Recommendations

The project work helped us a lot in understanding the practical aspects of fire & gas detection system in RELIANCE. During our project work, we came across various Firefighting Facilities at RELIANCE and the sophisticated fire and gas detection system in the plant. We witnessed as how to attend a Fire/Emergency call & Mock Drill. This project really helped us to understand the various fire protection systems & equipment in Tank storage area.

After worked for the whole scenario now I finally come over some standards facts and some safety measures for the company. Now on concluding my study I am here highlighting some modernized study by providing various recommendations to overcome the factor of risk and hazards. The work here provided one for the area of various recommendations which were effectively applied by me in the reliance plant.

According to Refinery policy strive to improve the Working performance by minimizing the risk of major and minor accidents, the risk to people's health and the environment to succeed we all need to:

1) Cooperate
2) Think before we act
3) Acquire knowledge
4) Report, investigate and learn from incidents
5) Follows instructions and regulations
6) Our safety regulations provides general requirements and information with the intent to minimize risks and ensure that the requirements of health and safety legislation as well as environmental legislation and environmental permit compliance
7) The refinery's safety regulations should be followed Safety training
8) Requirements for entering the refinery area (obtain a personal badge to pass):
   - Entre Basic
   - Entre Chemistry
   - Internal safety training
9) Visitors and staff not undergone training may be accompanied by visitor's receiver (staff or external staff with written permission) and report to reception on arrival.
10) As a visitors receiver you are responsible for informing your visitors about relevant risks, and that the visitor complies with applicable safety regulations.
11) Every meeting held the office where visitors present are to begin with information about what to do in case of fire (emergency).

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